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ART. XIII.—*Contributions to Meteorology;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Twentieth paper.

[Continued from page 17.]

Reduction of Barometric observations to sea-level.

I next proceeded to make a similar comparison of the observations at Summit station and Sacramento in California. These observations, which are in manuscript, were again loaned me by Prof. J. D. Whitney. Table VIII shows the principal barometric minima at Summit during a period of three years, and table IX shows the principal barometric maxima at Summit during the same period. The hours of observation were 7 A. M., 2 and 9 P. M. and these hours are indicated by the numerals 1, 2 and 3.

The numbers in each of these tables were arranged in the order of the mean temperatures, and divided into four equal groups, and the average of the numbers in each group was taken. The results are given in the first five columns of table III, and the numbers in the following columns were computed in the manner already explained for Mt. Washington. These results for barometric minima accord well with those for Pike's Peak; but for barometric maxima the differences between the observed reductions from Summit to Sacramento, and those computed by Ferrel's formula, are three times as great as for Mt. Washington, and more than twice as great as for Pike's Peak. A portion of this difference is unquestionably due to an error in the assumed mean temperature of the air column. This is shown by the observations at Colfax. For the California Meteorological observations, Prof. Whitney selected three stations, Sacramento, Colfax and Summit; the first station being elevated 31 feet above sea-level; the second 2425 feet and the third 7017 feet. These three stations are nearly in a straight line, and Colfax is nearly equidistant from the other two stations. The table at the bottom of the next page shows the mean temperature of each station for each month of the year.

TABLE VIII.—*Barometric minima at Summit, Cal.*

No.	Date.	Sacramento. Bar.	Sacramento. Ther.	Summit. Bar.	Summit. Ther.	Mean temp.	No.	Date.	Sacramento. Bar.	Sacramento. Ther.	Summit. Bar.	Summit. Ther.	Mean temp.
	1870.							1872.					
1	Oct. 15.3	29·755	63°	23·090	32°	47°·5	39	Feb. 4.3	29·956	58°	22·952	29·5	43°·7
2	23.1	·818	39	22·941	22	30·5	40	24.1	·560	46	·634	28·5	37·2
3	26.1	·774	41	·941	23	32	41	Mar. 5.2	·922	56	23·055	32	44
4	Nov. 6.2	·810	59	·898	35	47	42	11.2	·954	57	·008	30	43·5
5	26.2	·957	63	23·069	39	51	43	28.3	·876	57	·055	33	45
6	Dec. 2.2	·744	57	22·956	35	46	44	Apr. 6.1	·965	49	22·966	22	35·5
7	5.3	·866	44	·904	21	32·5	45	16.1	·825	46	·923	30	38
8	15.2	·928	46	·979	22	34	46	27.1	·975	49	23·028	28·5	38·7
	1871.						47	May 7.3	·815	53	22·929	30	41·5
9	Jan 10.1	·892	46	·918	26·5	36·2	48	14.1	·856	61	23·068	31	46
10	17.3	·924	45	23·058	32	38·5	49	Jun 16.1	·885	57	·062	48	52·5
11	23.2	·919	53	·054	30	41·5	50	Au. 19.2	·835	72	·199	57	64·5
12	28.2	30·049	56	·063	29	42·5	51	Sept. 2.3	·779	59	·077	43·5	51·2
13	Feb 10.2	29·957	55	·053	33·2	44·1	52	22.3	·942	54	·119	36	45
14	15.2	·882	45	22·921	27	36	53	Oct. 21.3	·905	54	·135	47	50·5
15	22.1	·585	37·5	·613	14	25·7	54	26.2	30·033	61	·142	32	46·5
16	Mar. 6.3	30·035	53	23·016	28·5	40·7	55	Nov. 8.2	29·886	62	·005	53	57·5
17	13.1	29·874	41	22·894	23	32	56	23.2	·967	57·5	·136	45	51·2
18	17.1	30·099	46	23·074	20	33	57	Dec 24.2	·925	53	·035	34	43·5
19	22.1	·029	38	·063	23	30·5	58	28.2	·686	53	22·959	35	44
20	Apr. 6.1	29·857	47·5	22·912	23	35·2	59	30.2	·873	54	23·041	36	45
21	16.3	·597	44	·727	21	32·5		1873.					
22	23.3	·859	67	23·096	29·5	48·2	60	Jan. 3.1	·933	49	·035	33	41
23	M'y 17.2	·883	68	·069	38·5	53·2	61	13.1	30·227	48	·151	30	39
24	28.3	·821	52	22·928	25	38·5	62	30.2	29·803	62	22·703	20	41
25	Jun 24.1	·902	54	23·184	43	48·5	63	Feb. 1.2	·652	44	·751	32	38
26	Jul. 26.3	·778	64	·165	49·5	56·7	64	8.3	·790	47	·905	32	39·5
27	Sep. 28.1	·908	52	·088	31	41·5	65	16.2	·969	57	·896	21	39
28	Oct. 27.3	·944	53·5	·165	31	42·2	66	18.1	·953	37	·914	18	27·5
29	Nov. 3.3	·957	52	22·993	28	40	67	24.1	·559	39	·593	24	31·5
30	11.2	·852	58	·940	24	41	68	27.1	·998	42	·977	25	33·5
31	26.2	·771	53	·705	27	40	69	Mar. 5.3	30·007	52·5	·917	28	40·2
32	28.3	·925	44	·973	23	33·5	70	26.1	·065	48	23·121	33	40·5
33	Dec 17.3	·785	47	·841	21	34	71	Apr. 4.1	·109	61	22·908	21	41
34	21.2	·543	50	·698	28	39	72	25.2	·101	67	23·088	49	58
35	23.1	·665	37	·700	29	33	73	M'y 15.1	29·941	55	·003	32	43·5
36	29.2	·751	54	·863	32	43	74	22.2	·971	78	·049	60	69
	1872.						75	28.1	·948	59	·005	30	44·5
37	Jan. 9.2	·875	47	·888	32	39·5	76	Jun 24.2	30·032	70·5	·051	41	55·7
38	24.1	·967	38	23·031	14·5	26·2							

Mean temperature of Sacramento, Colfax and Summit.

	Sacramento.	Colfax.	Summit.	Temp. excess.		Sacramento.	Colfax.	Summit.	Temp. excess.
January	47°·1	48°·1	29°·2	2°·02	July	73°·7	79°·8	61°·0	5°·23
February	48·8	44·2	27·3	1·35	August	71·3	78·5	59·1	5·69
March	54·8	51·6	31·6	2·38	September	67·4	71·0	53·6	4·16
April	59·3	54·1	33·8	1·77	October	60·2	63·2	46·3	3·88
May	65·5	63·9	43·9	2·90	November	50·8	52·0	34·3	3·43
June	70·9	73·4	54·9	3·99	December	45·4	47·2	29·1	3·69

TABLE IX.—*Barometric maxima at Summit, Col.*

No.	Date.	Sacramento. Bar.	Ther.	Summit. Bar.	Ther.	Mean temp.	No.	Date.	Sacramento. Bar.	Ther.	Summit. Bar.	Ther.	Mean temp.
	1870.							1872.					
1	Oct. 6.1	29·957	55°·5	23·469	51°·5	53°·5	46	Jan 17.3	30.260	47°·5	23·490	27°	37°·2
2	13.1	30·019	52·5	·470	48	50·2	47	22.1	·332	42	·522	24	33
3	19.1	·204	47·5	·635	45	46·2	48	Feb. 6.2	·254	51	·336	30	40·5
4	29.1	·262	39	·451	26·5	32·7	49	17.3	·137	58	·370	34·5	46·2
5	No. 14.1	·137	42·5	·499	35·5	39	50	19.2	·187	55	·360	33	44
6	18.3	·276	53	·643	37·5	45·2	51	Mar. 2.1	·376	47	·480	28·5	37·7
7	21.1	·290	43·5	·601	35	39·2	52	6.3	·292	52	·385	28·5	40·2
8	24.3	·218	53	·514	35·5	44·2	53	13.2	·321	56·5	·391	28	42·2
9	Dec. 9.3	·191	50	·375	24	·37	54	Apr 11.2	·296	60	·338	31	45·5
10	17.1	·316	28·5	·348	9	18·7	55	22.2	·093	76	·457	45	60·5
11	22·3	·384	37	·455	20·5	28·7	56	30.3	·146	66	·522	39	62·5
12	29·1	·300	36·5	·533	32·5	34.5	57	M'y 17.1	·033	67	·399	53	60
	1871.						58	28.1	·065	71	·453	46	58·5
13	Jan. 3.1	·279	34	·540	22	28	59	Jun. 9.1	29·901	65	·466	56	60·5
14	21.1	·367	36·5	·475	14·8	25·6	60	21.3	·929	78	·530	50	64
15	25.1	·213	39	·403	28	33·5	61	Au. 21.3	·910	72	·458	57	64·5
16	30.1	·376	36·5	·453	15·7	26·1	62	Sep 11.1	·988	67	·529	51	59
17	Feb. 2.1	·191	38	·355	28·5	33·2	63	14.1	·998	68	·557	59	63·5
18	12.3	·225	48	·344	20	34	64	Oct. 10.1	30·052	54	·533	46	50
19	17.1	·325	34·5	·387	20	27·2	65	17.1	·063	53	·520	50	51·5
20	25.3	·376	48	·531	28	38	66	Nov. 6.1	·312	41·5	·591	35	38·2
21	Mar. 2.3	·265	58	·445	23	40·5	67	18.1	·513	40	·695	26	33
22	8.2	·303	63·5	·399	40	51·7	68	20.1	·145	39	·584	35	37
23	11.2	·131	69·5	·358	47	58·2	69	Dec. 3.3	·243	46	·460	33	39·5
24	31.1	·216	51	·483	28	39·5	70	6.1	.017	57	·447	25	41
25	Apr 13.3	·146	57	·349	28	42·5	71	10.1	·165	37	·499	28	32·5
26	20.1	·245	49	·466	38	43·5		1873.					
27	25.2	·077	72	·344	49	60·5	72	Jan. 9.1	·246	48	·477	27	37·5
28	May 2.1	29·924	62·5	·357	49	55·7	73	15.3	·224	49	·536	35	42
29	14.2	30·022	68	·361	60	64	74	19.1	·243	42·5	·530	33	37·7
30	30.2	29·974	73·5	·438	59	66·2	75	Feb. 5.2	·499	56	·521	28	42
31	Jun 11.2	·948	71	·493	74	72·5	76	11.3	·331	50·5	·347	33	41·7
32	27.2	30·085	89	·537	71	80	77	21.3	·039	50	·494	22	36
33	Jul. 16.2	29·946	90	·495	75	82·5	78	Mar. 2.1	·451	36	·512	18	27
34	Au. 16.3	·994	66	·531	62	64	79	9.3	·213	57	·416	36	46·5
35	27.3	·896	79	·537	64	71·5	80	18.1	·089	50	·427	27	38·5
36	Sep 13.2	·878	88	·520	74	81	81	Apr. 7.2	·070	73	·550	38	55·5
37	Oct. 1.1	30·142	64	·552	47	55·5	82	15.2	·071	76	·515	51	63·5
38	16.1	·086	42	·479	38·5	40·2	83	May 6.1	29·778	42	·344	43	57·5
39	30.2	·116	64	·548	49	56·5	84	31.1	30·087	63·5	·382	38	50·7
40	No. 18.1	·250	40	·419	23	31·5	85	Jun 17.1	·066	68·5	·492	52	60·2
41	21.1	·425	40	·662	30	35	86	28.1	·180	64	·446	50	57
42	Dec. 4.3	·373	45	·579	23	34	87	Jul. 19.2	29·792	103	·489	70	86·5
43	9.3	·413	40·5	·526	32	36·2	88	27.3	·864	86	·534	70	78
44	14.1	·331	37	·663	31	34	89	Au. 20.1	30·084	54	·472	40	47
	1872.						90	24.2	29·882	81	·419	47	64
45	Jan 13.3	·228	51	·412	36	43·5							

If we assume that the mean temperature of the air column between Sacramento and Colfax is equal to the half sum of the temperatures at those stations, and similarly for the air column between Colfax and Summit, then the mean temperature of

the entire column between Sacramento and Summit will exceed the half sum of the temperatures at those two stations, by the quantities shown in column fifth of the above table. The differences of pressure due to these errors of temperature for the four lines in table III for barometric maxima at Summit, are

$$-\cdot036;\ -\cdot037;\ -\cdot053 \text{ and } -\cdot044.$$

Subtracting these numbers from the numbers in column eleventh of table III the differences are

$$-\cdot287;\ -\cdot185;\ -\cdot102 \text{ and } -\cdot007,$$

which are the discrepancies between theory and observation remaining to be explained; so that twenty-three per cent of the discrepancies appear to be due to the error in the assumed temperature of the air column. In about half of the cases, the barometric maxima occurred at Sacramento at the same time as at Summit (that is, within eight hours of the same instant). In two-thirds of the remaining cases, the maxima occurred first at Sacramento, so that the second cause appears to have only a slight influence at Summit. The main cause for these discrepancies appears to be the small range of the barometer at Sacramento, and the frequent want of correspondence between the barometric fluctuations at the two places. The following table shows, in decimals of an inch, the mean range of the barometer at Summit and Sacramento for each month as derived from the observations of three years.

	Summit.	Sacra'to.	Su.-Sa.		Summit.	Sacra'to.	Su.-Sa.
January	0·696	0·563	+0·133	July	0·317	0·369	—0·052
February ...	·861	·876	— ·015	August	·296	·329	— ·033
March	·552	·524	+ ·028	September ..	·456	·405	+ ·051
April	·660	·565	+ ·095	October	·540	·525	+ ·015
May	·492	·430	+ ·062	November ..	·797	·647	+ ·150
June	·421	·377	+ ·044	December...	·711	·700	+ ·011

For the three winter months, the mean monthly range of the barometer is ·043 inch greater at Summit than at Sacramento, whereas if the range was proportional to the mean pressure at the two stations, the range at Sacramento would exceed the range at Summit by ·261 inch.

The peculiarities of the observations at these stations are best shown by a graphic representation. The accompanying chart, plate II, shows the fluctuations of the barometer at Summit and Sacramento for the three months, Nov. 1870 and Jan. and April, 1873; and for the last two months I have added the curves for San Francisco derived from the Signal Service observations. We see that for Nov., 1870, there is a marked similarity in the curves at the two stations for the three prin-

cipal fluctuations, but the minor fluctuations at the two stations bear but little resemblance to each other, and the entire barometric range for the month at Sacramento is only two-thirds of that at Summit. The resemblance between the curves at Summit and Sacramento for Jan., 1873, is not quite as great, and the entire range for the month at Sacramento is less than two-thirds of that at Summit. The curve for San Francisco accords better with that at Summit than does the curve at Sacramento, and the range of the barometer is greater. For the month of April, 1873, there is not a single point of resemblance between the curves at Sacramento and Summit, and the entire range of the barometer at Sacramento is only 54 per cent of that at Summit At San Francisco, on the contrary, in the large fluctuations, the barometric curve shows considerable resemblance to that at Summit, and the range of the barometer is almost as great. These facts seem to furnish the clue to the anomalous character of the barometric observations at Sacramento. Sacramento is situated in a valley between two ranges of mountains. On the east are the Sierra Nevadas, 7000 feet in height, and on the southeast they rise to the height of 10,000 to 12,000 feet. On the west side, is the Coast Range of mountains, rising to the height of 3,000 to 4,000 feet, with a gap about fifty miles wide, through which flows the Sacramento river. From the summit of the Coast Range to the summit of the Sierra Nevadas, is but little more than 100 miles. In this valley of the Sacramento it is not possible that there should be much cyclonic motion of the winds. The winds at Sacramento almost always blow up or down the valley, and the winds from the three directions W., E. and N.E. form only eight per cent of the entire number for the year. The marked resemblance between the curves at San Francisco and Summit for the larger barometric fluctuations, seems to indicate that the cyclonic motion of the winds at San Francisco is sometimes propagated obliquely upward to the summit of the Sierra Nevadas, and in such cases it sometimes leaves no sensible trace of its influence at Sacramento. This comparative freedom of the air at Sacramento from cyclonic and anti-cyclonic disturbance, appears to be the chief cause of the anomalies noticed when we compare the observations at Summit and Sacramento. The value of the pressure coefficient which best satisfies the observations at Summit and Sacramento is 60449 and that of the temperature coefficient is $\frac{1}{1000}$.

I next proceeded to make a similar comparison of observations made at Grand St. Bernard and Geneva. As the Bibliothèque Universelle de Genève only gives the daily averages of the observations for 1877–9 (the observations employed in my fifteenth paper) I selected the years 1858, '59 and '60 for which

the observations are published in full for four hours each day, viz: 8 A. M., noon, 4 and 8 P. M. Table X shows the principal barometric minima at Grand St. Bernard during this period of three years, and table XI shows the principal barometric max-

TABLE X.—*Barometric minima at Grand St. Bernard.*

No.	Date.	Geneva. Bar.	Geneva. Ther.	Gr. St. Bernard. Bar.	Gr. St. Bernard. Ther.	Mean temp.	No.	Date.	Geneva. Bar.	Geneva. Ther.	Gr. St. Bernard. Bar.	Gr. St. Bernard. Ther.	Mean temp.
	1858.							1859.					
1	Jan. 5.1	726·56	— 4°6	556·75	—15°2	— 9°9	47	M'y 15.1	717·91	+ 8°0	555·95	— 4°9	+ 1°55
2	21.3	23·48	+ 0·7	53·20	—15·9	— 7·6	48	Jun. 2.4	17·98	+13·1	59·97	+ 1·0	+ 7·05
3	Feb. 2.2	25·86	+ 3·1	54·83	—18·7	— 7·8	49	10.1	18·20	+14·9	59·80	+ 1·5	+ 8·2
4	7.4	25·33	— 0·4	57·04	—12·9	— 6·65	50	Au. 31.3	22·55	+18·6	61·03	— 2·2	+ 8·2
5	16.1	20·13	+ 0·4	55·25	—10·3	— 4·95	51	Sep 17.1	13·22	+12·3	53·70	— 0·1	+ 6·1
6	22.3	19·89	+ 1 8	57·52	—13·3	— 5·75	52	Oct. 21.4	08·67	+12·8	52·26	— 1·0	+ 5·9
7	Mar. 1.1	13·29	+ 0·6	50·09	— 9·6	— 4·5	53	23.4	15·49	+ 0·4	52·27	— 3·0	— 1·3
8	7.1	09·66	— 5·6	41·07	—20·3	—12·95	54	29.4	13·97	+ 9·2	54·60	— 3·6	+ 2·8
9	12.1	21·33	0·0	51·80	—16·9	— 8·45	55	Nov. 4.4	14·02	+ 6·5	59·31	— 3·3	+ 1·6
10	15.1	18·10	+ 3·1	51·70	—10·2	— 3·55	56	17.2	25·48	+ 4·4	58·44	—12·0	— 3·8
11	Apr. 1.3	14·40	+12·1	53·86	— 3·1	+ 4·5	57	Dec. 2.1	12·11	+ 1·2	45·33	—15·6	— 7·2
12	11.3	17·73	+ 9·8	55·49	— 2·0	+ 3·9	58	15.3	16·43	— 4·4	45·14	—21·8	—13·1
13	27.3	21·65	+12·5	60·13	— 0·6	+ 5·95	59	19.4	16·21	— 4·9	46·69	—18·5	—11·7
14	May 3.2	12·72	+ 7·2	49·02	— 7·0	+ 0·1	60	26.2	09·14	+ 4·8	47·69	— 6·5	— 0·85
15	9.1	21·76	+ 4·4	55·43	— 7·4	— 1·5		1860.					
16	12.3	19·23	+11·9	57·48	— 0·8	+ 6·05	61	Jan. 5.5	11·08	+ 7·6	47·70	— 5·0	+ 1·3
17	25.2	22·05	+ 9·2	57·38	— 5·5	+ 1·85	62	23.1	14·70	+ 0·2	50·20	—11·9	— 5·85
18	Jul. 7.1	19·51	+14·2	60·01	+ 1·8	+ 8·0	63	25.1	10·79	+ 4·1	48·10	—11·7	— 3·8
19	30.1	23·78	+13·0	61·33	0·0	+ 6·5	64	31.1	10·61	+ 5·1	47·61	— 8·2	— 1·55
20	Au. 26.1	23·60	+14·1	60·52	— 2·6	+ 5·75	65	Feb. 6.4	28·61	+ 0·7	56·41	—14·2	— 6·75
21	28.3	21.39	+18·7	61·64	+ 2·6	+10·65	66	10.1	18·99	— 1·5	48·82	—15·8	— 8·65
22	Oct 20.1	18·99	+ 8·5	60·63	— 0·3	+ 4·1	67	16.4	18·01	— 4·9	49·48	—19·7	—12·3
23	29.3	28·70	+ 6·2	59·16	—11·4	— 2·6	68	20.3	12·16	— 0·2	44·45	—15·7	— 7·95
24	Nov. 5.2	26·19	— 0 4	54·77	—15·5	— 7·95	69	27.3	20·79	+ 6·7	52·01	— 7·0	— 0·15
25	7.1	25·17	+ 1·0	57·57	—11·0	— 5·0	70	Mar. 5.2	30·22	+ 3·8	58·40	—12·3	— 4·75
26	14.4	09·15	+ 5·1	51·53	— 1·0	+ 2·05	71	9·1	18·96	— 4·7	47·80	—21·4	—13·05
27	19.3	14·93	+ 9·6	55·19	— 2·3	+ 3·65	72	15·1	15·79	— 0·4	50·06	—11·2	— 5·8
28	28.1	13·90	+ 7 8	52·09	— 3·2	+ 2·3	73	25·1	15·73	+ 1·6	50·14	— 9·5	— 3·95
29	Dec. 6.1	24·80	+ 0·7	58·56	—10·3	— 4·8	74	Apr. 1.2	18·71	+13·7	56·20	— 1·5	+ 6·1
30	20.3	22·44	+ 4·0	56·46	— 9·3	— 2·65	75	10.3	18·49	+ 9·7	53·83	— 7·5	+ 1·1
31	27.4	15·39	+ 7·8	50·43	— 4·9	+ 1·45	76	20.1	14·27	+ 2·0	47·74	—13·0	— 5·5
	1859.						77	25.1	18·87	+ 4·4	53·33	— 7·4	— 1·5
32	Jan. 24.1	19·53	+ 2 6	55·61	—12·3	— 4·85	78	Jun 16.1	18·21	+11·6	58·71	— 0·2	+ 5·7
33	31.4	24·53	+ 0·2	59·16	— 8·7	— 4·25	79	Jul 28.3	19·97	+20·4	61·46	+ 6·2	+13·3
34	Feb. 3.1	21·87	+ 2·6	54·75	—11·7	— 4·55	80	Sep 19.3	17·84	+17·5	59·49	+ 3·4	+10·45
35	6.3	15·79	— 1·0	53·14	—10·8	— 5·9	81	Oct. 9.4	26·92	+ 9·0	57·98	— 6·6	+ 1·2
36	27.3	28·68	+ 5·7	59·48	—10·8	— 2·55	82	12.2	19·44	+ 2·6	52·54	— 3·1	— 0·25
37	Mar 15.2	21·78	+ 9·8	58·67	— 3·4	+ 3·2	83	Nov. 7.2	28·24	+ 2·0	56·39	—15·3	— 6·65
38	19.1	24·93	+ 4·0	59·87	— 6·1	— 1·05	84	18.2	23·60	+ 3·6	53·14	—13·5	— 4·95
39	23.1	25·65	+ 1·8	57·88	—12·1	— 5·15	85	25.1	15·63	+ 3·2	52·10	— 8·0	— 2·4
40	30.2	13·35	+ 5·0	50·34	— 4·4	+ 0·3	86	Dec. 4.3	16·28	+ 3·8	55·21	— 5·5	— 0·85
41	Apr 11.3	09·08	+10·7	48·68	— 5·5	+ 2·6	87	9·2	04·52	+ 4·4	43·45	— 5·8	— 0·7
42	14.1	13·85	+ 7·4	52·07	— 2·0	+ 2·7	88	11·2	12·79	+ 0·7	50·20	— 7·0	— 3·15
43	15.3	16·25	+ 8·0	52·23	— 7·3	+ 0·35	89	17·4	14·82	— 0·8	48·55	—16·6	— 8·7
44	22.2	13·90	+ 7·4	51·84	— 3·9	+ 1·75	90	19.4	15·16	— 1·9	50·78	—14·5	— 8·2
45	May 1.1	19·92	+ 8·8	59·08	— 1·2	+ 3·8	91	22.3	17·20	— 4·0	45·95	—20·0	—12·0
46	4.4	12·07	+10·5	52·34	— 1·8	+ 4·35	92	24.3	13·62	— 4·2	48·30	—14·9	— 9·55

ima during the same period. The hours of observation are indicated by the numerals 1, 2, 3 and 4.

The numbers in each of these tables were arranged in the order of the mean temperatures, and divided into four equal groups as explained in the preceding cases. The first five columns of table III show the average results, and the numbers in the following columns were computed in the manner hereto-

TABLE XI.—*Barometric maxima at Grand St. Bernard.*

No.	Date.	Geneva. Bar.	Geneva. Ther.	Gr. St. Bernard. Bar.	Gr. St. Bernard. Ther.	Mean temp.	No.	Date.	Geneva. Bar.	Geneva. Ther.	Gr. St. Bernard. Bar.	Gr. St. Bernard. Ther.	Mean temp.
	1858.							1859.					
1	Jan. 1.1	739·90	— 3°8	573·76	— 0°6	— 2°2	43	M'y 11.1	726·62	+ 15°3	566·22	+ 4°2	+ 9°75
2	10.4	36·19	— 2·0	69·34	— 6·7	— 4·35	44	Jun. 7.2	26·39	+ 21·5	68·73	+ 8·5	+ 15·0
3	19.4	36·81	— 2·6	67·72	—11·7	— 7·15	45	23.3	29·92	+ 25·8	71·94	+ 8·4	+ 17·1
4	30 2	38·08	— 5·7	67·83	— 8·8	— 7·25	46	27.2	30·39	+ 25·5	74·56	+ 14·7	+ 20·1
5	Feb. 5.4	30·17	+ 3·0	64·75	— 7·6	— 2·3	47	July 3.4	30·00	+ 24·0	76·85	+ 15·3	+ 19·65
6	12.4	31·89	+ 0·8	66·97	— 7·6	— 3·4	48	13.2	32·26	+ 25·7	75·34	+ 14·4	+ 20·05
7	Mar 17.4	33·19	+ 3·7	67·42	— 6·6	— 1·45	49	Aug. 4.1	28·48	+ 24·6	73·50	+ 12·1	+ 18·35
8	23.2	35·91	+ 9·8	71·62	+ 2·2	+ 6·0	50	12.2	27·92	+ 22·4	71·31	+ 10·8	+ 16·6
9	28.4	28·11	+ 6·5	64·93	— 4·3	+ 1·1	51	Sep 10.2	29·80	+ 23·6	70·89	+ 10·9	+ 17·25
10	Apr. 4.4	27·24	+ 10·1	65·23	— 3·5	+ 3·3	52	26.1	32·89	+ 14·3	74·41	+ 9·1	+ 11·7
11	16.4	30·26	+ 14·4	69·99	— 2·9	+ 5·75	53	Oct. 2.2	34·38	+ 21·5	74·98	+ 8·2	+ 14·85
12	23.4	30·63	+ 15·8	71·14	+ 2·4	+ 9·1	54	17.4	28·16	+ 11·9	68·24	+ 1·5	+ 6·7
13	M'y 18.2	30·91	+ 17·2	70·36	+ 8·7	+ 12·95	55	Nov. 6.4	29·82	+ 13·7	70·59	+ 3·9	+ 8·8
14	22.3	27·01	+ 22·9	69·78	+ 7·1	+ 15·0	56	13·4	33·82	— 0·8	68·13	— 6·9	— 3·85
15	Jun. 1.2	32·10	+ 20·2	73·75	+ 9·9	+ 15·05	57	19·2	34·27	+ 0·3	68·66	— 0·6	— 0·15
16	14.4	27·00	+ 23·0	72·47	+ 8·8	+ 15·9	58	26·4	29·17	+ 0·6	66·45	— 4·0	— 1·7
17	19.4	30·27	+ 21·4	71·99	+ 6·4	+ 13·9	59	Dec. 9.2	37·88	+ 1·6	70·58	— 0·8	+ 0·4
18	Jul 18.4	29·72	+ 23·6	73·44	+ 8·3	+ 15·95	60	31.3	32·96	+ 9·4	69·08	— 1·9	+ 3·75
19	Aug. 5.4	28·86	+ 22·1	72·28	+ 7·5	+ 14·8		1860.					
20	16.2	30·84	+ 20·2	71·84	+ 10·1	+ 15·15	61	Jan. 9.1	38·00	— 5·5	71·16	— 5·3	— 5·4
21	Sep. 12.4	30·42	+ 16·6	72·72	+ 4·5	+ 10·55	62	16.4	34·33	+ 1·4	68·50	— 5·8	— 2·2
22	20.4	31.87	+ 18·9	73·71	+ 6·8	+ 12·85	63	Feb. 5.1	33·33	— 6·5	64·14	— 8·4	— 7·45
23	27.2	32·71	+ 17·8	72·61	+ 6·8	+ 12·3	64	7.4	34·80	— 0·6	63·08	—15·5	— 8·05
24	Oct. 4.1	30·96	+ 9·0	70·98	+ 2·0	+ 5·5	65	25.4	33·06	— 0·9	65·53	— 9·6	— 5·25
25	14.4	32·58	+ 7·9	71·19	+ 3·6	+ 5·75	66	Mar. 4.1	36·39	— 1·7	66·85	— 9·0	— 5·35
26	Nov 11.4	33·73	— 4·0	67·27	— 7·0	— 5·5	67	6.3	35·64	+ 1·2	63·70	—15·6	— 7·2
27	Dec 11.4	32·37	+ 0·2	66·19	— 7·4	— 3·6	68	20.2	33·73	+ 6·8	67·66	— 5·2	+ 0·8
28	17.1	33·43	— 2·0	67·14	— 7·9	— 4·95	69	Apr. 6.1	23·63	+ 8·9	62·13	— 2·5	+ 3·2
29	22.4	31·94	+ 4·5	66·59	— 4·7	— 0·1	70	16.4	28·04	+ 9·8	65·26	— 4·0	+ 2·9
	1859.						71	30.2	29·38	+ 10·2	67·07	+ 0·6	+ 5·4
30	Jan 10.4	44·25	— 6·2	73·60	— 8.2	— 7·2	72	M'y 11.2	27·74	+ 18·0	69·89	+ 4·5	+ 11·25
31	17.4	36·35	0·0	69·36	— 9.9	— 4·95	73	21.2	30·53	+ 20·8	69·70	+ 5·8	+ 13·3
32	21.4	36·93	— 2·0	70·21	— 9,8	— 5·9	74	Jun 26.2	27·94	+ 29·2	72·32	+ 13·4	+ 21·3
33	Feb 17.2	36·91	+ 9·3	70·71	— 1.9	+ 3·7	75	Jul. 3.2	33·16	+ 19·5	71·53	+ 7·3	+ 13·4
34	22.4	35·69	— 0·9	67·75	— 6.5	— 3·7	76	Au. 19.4	31·45	+ 14·9	70·16	+ 4·9	+ 9·9
35	25.2	35·33	+ 5·6	69·71	— 2.5	+ 1·55	77	26.4	26·32	+ 22·0	71·58	+ 11·5	+ 16·75
36	Mar. 5.4	36·09	+ 11·2	73·03	+ 3·0	+ 7·1	78	Sep 22.2	30·18	+ 16·6	70·39	+ 7·5	+ 12·05
37	12.2	34·23	+ 17·8	70·90	— 0·8	+ 8·5	79	Oct. 3.2	35·49	+ 13·5	70·56	+ 0·4	+ 6·95
38	20.4	33·53	+ 7·0	67·83	— 5·8	+ 0·6	80	7.2	35·00	+ 11·2	72 80	+ 7·0	+ 9·1
39	Apr. 4.4	33·25	+ 9·6	71·89	+ 0·7	+ 5·15	81	21.2	32·98	+ 12·0	70·82	+ 6·9	+ 9·45
40	7.4	29·49	+ 17·8	71·06	+ 3·0	+ 10·4	82	26.4	32·36	+ 8·6	70·77	+ 1·0	+ 4·8
41	26.4	27·51	+ 13·1	68·24	+ 1·9	+ 7·5	83	N'v 29.2	25·38	+ 4·6	65·91	— 2·4	+ 1·1
42	May 6.4	25·79	+ 12·2	65·24	+ 0·3	+ 6·25	84	Dec 29.4	35·10	— 3·6	64·99	—15·5	— 9·55

fore explained. In tables X and XI the pressures are given in millimeters and the temperatures in centigrade degrees; but for convenience of comparison, the results in table III are given in English units. The results for barometric minima accord well with those for Pike's Peak and Summit, but for barometric maxima the observed values differ from the computed values less than for either of the preceding cases. Can these differences be ascribed wholly to the error in the assumed temperature of the air column? In order to decide this question, I have examined the observations made by Plantamour at several stations in the neighborhood of Mt. Blanc and published in Mémoires de la Société de Physique de Genève, volume xv, pp. 399–403. The following table gives a summary of the results.

Station.	Altitude meters.	No. of Obs.	Thermometer.			M. temp. $-\frac{1}{2}$ sum.
				Geneva.	St. Ber.	
Serraval	840	22	16°·41	17°·88	5°·55	+0°·57
Chamounix	1044	11	12·16	15·89	2·44	+ 0·22
Evoléna	1379	7	11·63	17·11	2·43	+ 0·73
Bourg St. Pierre	1640	22	11·16	17·40	5·52	+ 0·44
Cantine de Proz	1809	11	12·39	19·24	9·60	— 0·14

Column first gives the name of the station; column second its altitude in meters; column third the number of observations made; column fourth the mean of the observations made at the stations named in column first; columns fifth and sixth the mean of the observations made at Geneva and St. Bernard at the same hours; column seventh shows the difference between the half sum of the temperature at Geneva and St. Bernard and the mean temperature of the air column deduced from the observations in the manner heretofore explained. The mean of the differences in column seventh is 0°·40 Cent. or 0°·72 Fahr. These observations were all made in the months of July, August and September, and the above difference has an algebraic sign opposite to that of the difference in table III for the summer months. If then we apply a correction for the error in the assumed temperature of the air column, we only increase the discrepancies which are to be explained.

The barometric minima at St. Bernard for the three years here employed, occurred on an average 4·7 hours later than at Geneva. St. Bernard is 50 miles east of Geneva and a barometric minimum travels this distance in three hours, so that at St. Bernard the barometric minima appear to be retarded 1·7 hours on account of elevation. The discrepancies shown in table III are to be ascribed partly to this retardation but mainly to the dissimilarity of the barometric curves at the two stations.

The value of the pressure coefficient which best satisfies the observations at Grand St. Bernard and Geneva is 60300, and that of the temperature coefficient is $\frac{1}{960}$.

I next proceeded to make a comparison of observations made at Colle di Valdobbia and Alessandria. As the Moncalieri Bulletin only gives the daily averages of the observations for 1877–79, I selected for examination the years 1879, '80 and '81, for which the observations are published in full for three hours each day (viz: 9 A. M., 3 and 9 P. M.) in the Annali dell Ufficio

TABLE XII.—*Barometric minima at Colle di Valdobbia.*

No.	Date.	Alessandria. Bar.	Alessandria. Ther.	C.diValdobbia Bar.	C.diValdobbia Ther.	Mean temp.
	1879.					
1	Jan. 4.2	746·9	5°8	553·0	— 5°9	— 0°05
2	8.3	43·6	—2·3	45·4	—15·2	— 8·75
3	21.2	55 6	—0·2	55 9	— 8·5	— 4·35
4	Feb 11.2	34·3	6·7	45·2	— 1·7	+ 2·5
5	17.2	30·2	10·8	44·0	— 6·5	+ 2·15
6	20.3	35·1	3·4	41·7	— 8·5	— 2·55
7	23.1	26·3	1·8	37·0	— 7·9	— 3·05
8	25.2	30·7	1·7	40·2	— 7·7	— 3·00
9	Mar 23.2	40·5	11·3	51·0	— 2·8	+ 4·25
10	28.1	44·2	9·2	52·6	— 5·3	+ 1·95
11	Apr. 8.1	38·4	8·8	48·9	— 3·7	+ 2·55
12	12.3	38·8	9·0	48·2	— 5·8	+ 1·6
13	17.1	38·0	10·2	47·4	— 5·5	+ 2·35
14	May 7.2	43·5	17·5	54·2	0·7	+ 9·1
15	10.1	41·4	9·3	51·0	— 2·2	+ 3·55
16	Jun 17.2	46·6	23·5	59·3	3·5	+13·5
17	Jul. 21.3	42·9	21·4	58·5	2·6	+12·0
18	Oct 16.2	40·5	10·0	51·3	— 2·2	+ 3·9
19	21.1	42·2	10·8	53·9	- 2·2	+ 4·3
20	Nov. 3.1	45·6	9·7	54·6	— 7·6	+ 1·05
21	13.1	47·9	—0·8	53·6	—10·5	— 5·65
22	20.1	50·2	1·2	54·1	—11·7	— 5·25
23	26.3	46·1	4·2	51·9	— 9·7	— 2·75
24	Dec. 1.2	39·4	1·8	43·4	—15·0	— 6·6
25	5.1	40·0	—5·6	44·9	—11·6	— 8·6
	1880.					
26	Jan 17.1	54·0	—11·1	52·7	—12·4	—11·75
27	22.3	59·0	—4·6	57·7	—13·5	— 9·05
28	Feb 10.2	50·8	1·3	55·8	— 4·9	— 1·8
29	18.1	48·4	3·3	55·3	— 5·1	— 0·9
30	23.2	45·7	6·8	52·2	— 5·3	+ 0·75
31	27.2	45·8	8·8	53·8	— 6·2	+ 1·3
32	Mar 31.2	45·5	17·5	56·7	0·0	+ 8·75
33	Apr. 2.1	49·1	7·3	56·0	— 3·6	+ 1·85
34	7.1	39·5	7·9	49·7	— 4·8	+ 1·55
35	27.2	45·4	13·2	56·5	— 2·2	+ 5·5
36	May 3.1	45·5	13·0	55·7	2·6	+ 7·8
37	8.2	41·0	11·5	53·6	— 1·0	+ 5·25
38	19.1	46·6	11·7	56·1	— 3·0	+ 4·35
39	Jun. 5.1	47·0	17·5	59·0	6·2	+11·85
40	Aug. 3.1	43·9	20 5	58·4	5·9	+13·2
41	Sep 16.1	744·4	17°9	557·3	2°5	+10°2
42	Oct. 12.1	49·3	12·7	59·1	0·1	+ 6·4
43	20.2	47·5	16·8	58·9	2·7	+ 9·75
44	29.3	42·1	11·4	54·4	— 2·1	+ 4·65
45	Nov. 3.2	52·0	4·8	57·3	— 9·5	— 2·35
46	17.2	35·4	9·4	47·1	— 1·8	+ 3·8
47	21.3	50·0	7·7	58·6	— 3·5	+ 2·1
48	Dec 17.2	50·0	7·5	57·4	— 2·0	+ 2·75
49	21.2	49·8	5·9	56·7	— 7·2	— 0·65
50	25.2	43·5	2·2	52·0	— 3·4	— 0·6
51	31.1	52·2	4·8	57·0	—10·3	— 2·75
	1881.					
52	Jan 13.3	38·6	1·1	45·3	—11·0	— 5·0
53	15.2	40·7	—0·2	44 7	—11·7	— 5·95
54	20.1	41·6	—6·3	45·7	—14·0	—10·15
55	23.1	49·3	—6·9	51·8	—12·8	—10·35
56	30.1	42·1	0·1	50·8	— 8·3	— 4·1
57	Feb. 6.1	46·1	—4·0	51·9	— 7·9	— 5·95
58	9.1	45·1	—6·0	53·0	— 8·7	— 7·35
59	11.3	35·5	3·0	44·9	— 8·3	— 2·65
60	Mar. 1.2	43·8	7·2	51·6	— 8·6	— 0·7
61	22.2	46·2	13·6	52·5	—12·2	+ 0·7
62	25.2	45·3	5·5	52·5	— 1·8	+ 1·85
63	30.2	43·4	12·3	55·0	— 0·5	+ 5·9
64	Apr. 3.2	42·0	16·8	54·9	2·4	+ 9·6
65	5.2	45·7	12·7	56·1	— 0·7	+ 6·0
66	20.2	36·2	18·9	50·1	1·5	+10·2
67	22.2	36·9	15·1	48·8	— 3·8	+ 5·65
68	May 3.2	49·1	10·7	58·3	0·3	+ 5·5
69	Jun. 8.1	39·7	15·3	51·4	— 2·8	+ 6·25
70	Au. 17.2	43·8	20·1	59·1	9·4	+14·75
71	Sept. 1.2	41·9	15·4	57·0	0·1	+ 7·75
72	22.2	43·8	22·4	58·2	4·5	+13·45
73	Oct. 4.2	47·4	13·2	57·1	0·8	+ 7·0
74	21.2	43·2	8·0	53·4	— 1·6	+ 3·2
75	25.2	40·6	12·6	53·9	2·1	+ 7·35
76	31.1	44·1	7·3	53·1	— 6·1	+ 0·6
77	Nov. 2.2	45·7	16·5	56·7	— 0·9	+ 7·8
78	28.2	54·9	7·4	59·7	— 3·2	+ 2·1
79	Dec 11.2	45·0	1·7	53·9	— 6·0	— 2·15
80	20.2	45·0	3·5	49·9	— 5·5	— 1·0

Centrale di Meteorologia Italiana. Table XII shows the principal barometric minima at Colle di Valdobbia during this period of three years, and table XIII shows the principal barometric maxima during the same period. The hours of observation are indicated by the numerals 1, 2 and 3.

TABLE XIII.—*Barometric maxima at Colle di Valdobbia.*

No.	Date.	Alessandria.		C.di Valdobbia		Mean temp.	No.	Date.	Alessandria.		C.di Valdobbia		Mean temp.
		Bar.	Ther.	Bar.	Ther.				Bar.	Ther.	Bar.	Ther.	
	1879.		°		°			1880.		°		°	
1	Jan 1.1	759·2	2·0	566·1	− 2·6	− 0·3	47	Au 28 1	756·6	21·1	569·8	8·6	+ 14·85
2	13.3	61·1	−3·2	66·2	− 6·5	− 4·85	48	31.3	57·3	19·0	69·9	6·5	+ 12·75
3	27.1	59·6	3·9	65·0	− 5·2	− 0·65	49	Sep. 2.3	61·0	20·9	74·7	7·9	+ 14·4
4	Feb 7.1	54·6	−0·6	61·4	− 5·5	− 3·05	50	Oct. 1.1	61·2	13·3	72·2	2·9	+ 8·1
5	9.1	56·7	5·9	62·6	− 4·5	+ 0·7	51	15.3	58·5	11·5	67·7	2·6	+ 7·05
6	Mar. 9.3	65·8	7·7	72·3	− 3·0	+ 2·35	52	Nov 7.3	61·9	8·8	68·9	− 2·4	+ 3·2
7	17.1	58·0	4·2	63·1	− 3·4	+ 0·4	53	24.3	64·1	8·2	69·5	− 1·8	+ 3·2
8	Apr. 1.1	55·6	13·5	63·4	− 0·8	+ 6·35	54	29.3	67·3	6·8	73·2	− 1·5	+ 2·65
9	25.3	49·1	15·9	61·0	− 3·9	+ 6·0	55	Dec. 8.1	67·1	− 1·0	74·8	1·0	0·
10	May 5.3	55·7	14·0	63·5	− 3·1	+ 5·45	56	11.1	55·4	2·2	66·1	− 0·2	+ 1·0
11	14.3	54·4	14·6	64·0	− 1·0	+ 6·8		1881.					
12	22.3	55·7	16·0	67·6	0·5	+ 8·25	57	Jan. 2.3	64·6	1·8	66·2	−11·7	− 4·95
13	30.1	59·7	12·1	66·7	0·5	+ 6·3	58	6.3	58·5	5·9	64·5	− 5·6	+ 0·15
14	Ju. 11.3	56·0	22·0	70·4	5·9	+ 13·95	59	Feb 3.1	55·9	− 5·1	61·7	− 7·7	− 6·4
15	21.3	52·3	25·5	68·3	7·4	+ 16·45	60	16·3	57·9	3·0	61·9	− 5·8	− 1·4
16	28.2	55·4	30·7	72 5	12·4	+ 21·55	61	21·3	61·4	7·2	65·9	− 4.5	+ 1·35
17	Jul 25.3	54·8	23·9	70·4	9·4	+ 16·65	62	23·3	60·8	5·5	65·0	− 8·4	− 1·45
18	28.3	56·4	23·9	71·5	8·8	+ 16·35	63	Mar. 3.1	60·9	0·6	62·9	− 7·5	− 3·45
19	Aug 3.1	54·4	26·1	72·4	16·0	+ 21·05	64	9.3	56·2	10·3	66·4	− 2·3	+ 4·0
20	20.3	53·5	24·7	70·6	11·9	+ 18·3	65	18.3	62·4	10·8	71·5	− 1·0	+ 4·9
21	29.3	54·7	24·8	71·4	12·3	+ 18·55	66	23.3	57·7	8·7	62·5	− 7·5	+ 0·6
22	Sep. 2.1	59·4	24·5	73·8	12·4	+ 18·45	67	Ap 17.3	54·9	16·3	64 1	− 0·3	+ 8·0
23	Oct. 8.3	55·9	16·5	70·3	8·3	+ 12·4	68	25.3	55·1	11·6	63·5	− 2·5	+ 4·55
24	12.3	62·1	14·4	72·8	7·0	+ 10·7	69	30.3	57·0	12·1	65·2	− 1·5	+ 5·3
25	Nov 5.3	62·6	5·7	69·3	− 2·8	+ 1·45	70	May 7.2	61·9	22·4	72·6	8·9	+ 15·65
26	8.3	65·4	5·7	71·7	1·0	+ 3·35	71	22.1	56·8	19·5	69·7	6·8	+ 13·15
27	22.1	66·0	3·2	69·8	− 3·3	− 0·05	72	30.3	56·1	16·8	67·4	3·5	+ 10·15
28	D'c 16.1	68·1	−7·5	68·6	− 8·8	− 8·15	73	Jun 4.2	54·0	26·8	68·3	6·2	+ 16·5
29	23.1	71·0	−7·8	75·2	− 4·5	− 6·15	74	17.3	53·8	20·7	68·3	6·6	+ 13·65
30	28.3	69·0	−8·2	71·9	− 4·6	− 6·4	75	24.3	56·1	25·3	72·8	10·5	+ 17·9
	1880.						76	July 4.3	57·8	27·7	75·7	14·3	+ 21·0
31	Jan. 4.3	65·3	−2·0	70·1	− 3·2	− 2·6	77	15.1	59·7	26·8	75·5	15·2	+ 21·0
32	7.1	67·1	−8·4	71·0	− 4·0	− 6·2	78	18.3	53·9	29·4	72·9	14·4	+ 21·9
33	31.1	65·1	2·3	69·5	− 5·2	− 1·45	79	29.2	59·2	27·6	72·7	11·0	+ 19·3
34	Feb. 1.1	66·3	2·1	69·4	− 6·7	− 2·3	80	Aug 4.3	58·7	26·0	74·5	9·6	+ 17·8
35	3.3	64·8	−0·6	69·9	− 6·2	− 3·4	81	20.3	54·4	22·5	70·0	9·6	+ 16·05
36	Mar. 6.3	58·7	13·1	70·1	2·0	+ 7·55	82	29.3	57·3	18·3	70·0	5·9	+ 12·1
37	9.1	66·3	11·4	72·1	− 1·0	+ 5·2	83	Sep 13.3	59·1	17·7	69·7	4·0	+ 10·35
38	11.3	61·1	10·8	70·9	1·6	+ 6·2	84	18.3	56·0	21·0	70·1	10·4	+ 15·7
39	Ap 19.1	56·1	14·9	66·3	3·5	+ 9·2	85	26.1	58·3	13·5	68·0	5·9	+ 9·7
40	My 25.3	61·0	19·0	73·1	6·7	+ 12·85	86	Oct. 7.2	58·9	15·6	68·8	1·2	+ 8·4
41	Ju. 17.2	53·3	24·7	67·0	6·8	+ 15·75	87	Nov. 5.3	67·1	10·0	74·1	1·7	+ 5·85
42	28.3	56·8	21·8	71·3	7·8	+ 14·8	88	13.3	60·8	6·0	72·3	3·1	+ 4·55
43	Jul 11.2	55·0	29·4	70·6	10·6	+ 20·0	89	20.1	66·3	4·7	71·0	1·8	+ 3·25
44	16.3	54·6	26·2	72·3	13·0	+ 19·6	90	24.3	66·2	7·0	71·3	− 3·0	+ 2·05
45	19.2	55·3	32·6	73·2	17·0	+ 24·8	91	Dec. 2.1	62·1	5·9	67·3	− 5·2	+ 0·35
46	Au 25.3	54·1	22·8	69·1	9·6	+ 16·2	92	27.3	69·4	−0·5	75·8	1·6	+ 0·5

Table III shows the results deduced from these observations in the manner already fully explained, the pressures being expressed in English inches, and the temperatures in degrees of Fahrenheit. These results do not differ very widely from those found for Grand St. Bernard, but the discrepancies between theory and observation are somewhat greater. The first question then is can these discrepancies be explained by the error in the assumed temperature of the air column? In order to answer this question I have sought for observations of the thermometer at stations intermediate between Colle di Valdobbia and Alessandria and have found two, viz: Biella, elevated 434 meters above the sea, and Cogne, elevated 1543 meters. The following table shows the mean temperatures of the four stations for each month of the year, deduced from the three years 1879–81. The sixth column shows the difference between the mean temperature of the air column and the half sum of the temperatures of the upper and lower stations. The sign + indicates that the former exceeds the latter.

	Aless'a.	Biella.	Cogne.	Valdo'a	Temp. excess.		Aless'a	Biella.	Cogne.	Valdo'a	Temp. excess.
	°	°	°	°	°		°	°	°	°	°
Janu'y	−2·53	−0·43	−6·80	−8·63	+0·58	July ..	24·13	21·37	15·47	9·27	−0 17
Febr'y	2·47	3·50	−3·63	−6·50	+0·31	Aug'st	23·30	20·50	15·10	9·80	−0·38
March	8·37	7·33	+1·10	−2·73	−0·17	Sept. .	18·47	15·97	10·30	5·40	−0·40
April .	12·07	9·87	3·37	−1·63	−0·36	Oct. ..	12·00	11·00	4·83	0·67	−0·04
May ..	15·37	13·20	7·27	+1·40	−0·01	Nov...	6·23	5·77	+0·57	−2·83	+0·10
June..	20·37	17·70	12·00	5·10	+0·11	Dec. ..	−0·03	1·87	−4·27	−6·20	+0·55

This table shows that in winter the mean temperature of the air column is almost 1° Fahr. greater than the half sum of the temperatures of the upper and lower stations, and in summer the former temperature is a little less than the latter; but this error will only explain about ten per cent of the discrepancy between theory and observation shown in table III.

Somewhat more than half of the barometric minima occur at the same hour (i. e. the same hour of observation) both at Colle di Valdobbia and Alessandria. On an average for the three years, the barometric minima occur at Valdobbia three quarters of an hour later than at Alessandria, and allowing for difference of longitude, the actual retardation at Valdobbia is at least three hours. The barometric maxima occur at Valdobbia on an average three and one-half hours later than at Alessandria, and allowing for difference of longitude the actual retardation is about six hours. This will explain a portion of the discrepancies between theory and observation shown in table III, but the principal part is due to the dissimilarity of the barometric curves at the upper and lower stations; i. e. to the dissimilar movements of the upper and lower strata of the atmosphere.

The value of the pressure coefficient which best satisfies the observations at Colle di Valdobbia and Alessandria is 60418 and that of the temperature coefficient is $\frac{1}{1051}$.

It will be noticed that in all of the preceding cases (except California) the error arising from assuming that the mean temperature of the air column is equal to the half sum of the temperatures at the upper and lower stations is quite small. I have endeavored to obtain information relating to the same question from other parts of the world. In the Indian Meteorological Memoirs, vol. ii, p. 135, is given a table showing the vertical decrement of temperature in the Himalaya Mountains for each month of the year at intervals of 1000 feet up to 12,000 feet. From this source I have derived the following table, in which column second shows the mean decrement of temperature for each 1000 feet of elevation for the three winter months, and column third shows the same for the three summer months.

Height in feet.	Winter.	Sum'er.	Height in feet.	Winter.	Sum'er.
0 to 1,000	1°·60	4°·00	4,000 to 5,000	2°·08	3°·57
1,000 to 2,000	1·67	3·98	5,000 to 6,000	2·30	3·30
2,000 to 3,000	1·77	3·91	6,000 to 7,000	2·54	2·97
3,000 to 4,000	1·91	3·77	7,000 to 8,000	2·83	2·59

From these numbers we find that in winter, for an elevation of 8000 feet, the mean temperature of the air column is greater than the half sum of the temperatures of the upper and lower stations by 0°·82 Fahr.; and in summer the former is less than the latter by 0°·94 F. These results are similar to those found for the southern slope of the Alps. The observations in the Sacramento valley make the mean temperature of the air column greater than the half sum of the temperatures at the upper and lower stations at all seasons of the year, but the effect in summer is much greater than in winter. The observations on Mt. Washington and on the northern slope of the Alps indicate an effect for summer similar to that in California, but much smaller in amount.

The average value of the barometric coefficient deduced from the observations at the five stations employed in this investigation, is 60379, and the value of the thermometric coefficient is $\frac{1}{1000}$. Hence the Laplace formula becomes

$$H = 60379 \text{ ft.} \times \log. \frac{B}{B'} \times \left\{ \begin{array}{l} \left(1+\frac{t+t'-64}{1000}\right) \\ (1+0{\cdot}002606 \cos 2L) \\ \left(1+\frac{H+52252}{20886860}+\frac{S}{10443430}\right) \end{array} \right.$$

The reduced pressures computed from this formula are shown in column twelfth of table III, and the differences between the observed and computed values are shown in the last column. In computing the reductions from Summit to Sacramento, I have applied to the half sum of the temperatures at the upper and lower stations, the corrections shown on page 20. In the four other cases I have applied no such correction because this correction appears to be quite small, and its precise value is not very well determined. We see that with low pressures the computed reduction to the lower station is (with one trifling exception) always too small; but with high pressures the computed reduction is (with two trifling exceptions) always too great. It has been shown that only a small part of these differences can be ascribed to the error in the assumption that the mean temperature of the air column is equal to the half sum of the temperatures at the upper and lower stations. The discrepancies are mainly due to the dissimilarity in the curves representing the barometric fluctuations at the two stations.

In consequence of this dissimilarity, it happens that when the barometer on the top of a mountain is at a minimum, the barometer at its base is generally not exactly at its minimum, or it is a minimum of an inferior order. The barometer at the base is therefore higher than it would be if there was an exact correspondence between the barometric movements at the two stations, and the observed difference between the upper and lower barometers is greater than that which theory would indicate. On the contrary, when the barometer on the top of the mountain is at a maximum, the barometer at the base is generally not exactly at its maximum, or it is a maximum of an inferior order. The barometer at the base is therefore lower than it would be if there was an exact correspondence between the barometric movements at the two stations, and the observed difference between the two barometers is less than that which theory would indicate.

Hence we see the utter hopelessness of discovering a formula which shall exactly represent the barometric reduction to sea-level at all pressures and temperatures, unless the formula takes account of these dissimilar movements in the upper and lower strata of the atmosphere; and since these movements are greatly modified by the obstruction of the mountains upon which the observations are made, and therefore vary with the locality, such an attempt seems a hopeless undertaking.

ART. XIV.—*Notes on the Rocks and Ore-Deposits in the vicinity of Notre Dame Bay, Newfoundland;* by M. E. WADSWORTH.

INTRODUCTORY.

THIS paper has been written for the purpose of presenting some of the results of a short trip to the island of Newfoundland in the summer of 1880. Since the object of the journey was a commercial one in behalf of parties interested in some ore deposits about the Notre Dame Bay, the observations and collections were naturally confined to the immediate vicinity of the mineral lands, and limited as to time.

In the descriptions of the rocks collected the object has been rather to describe the rock structure and to trace its history, than to enter upon elaborate descriptions of the contained minerals. The principles employed for the nomenclature here given are those announced in the Bulletin of the Museum of Comparative Zoology, 1879, v, 275–278, and employed in my later petrographical papers.

The key note is the belief that a large portion of the older rocks now designated by various names were once identical with their modern representatives, and that the present differences of the former from the latter are due chiefly, if not entirely, to secondary changes since the time of eruption. The older rocks are classed as varieties under the modern species whose altered form they are supposed to be, and the mineral composition is regarded not as a fixed but a changing factor. Hence the traces of the original minerals and of the original structure of rock are here allowed much greater weight in nomenclature than is given to the secondary or alteration minerals, which now form the chief mass of these older rocks.

The districts examined were chiefly various points between Exploits Burnt Island and Betts Cove.

THE BASALT ROCKS.

Melaphyr (Lava Flows).

Much of the coast of Exploits Burnt Island is formed by a series of lava flows. These flows are seen to have rolled and tumbled over one another down the steep slopes in huge rounded botryoidal and link-like masses resembling in their irregular rocky structure a writhing mass of huge anacondas or a pile of Bologna sausages. A succession of these flows has taken place, the stiffening lava, like heavy tar, slowly tumbling over the preceding flows and building up steep slopes. The lines of motion and the scum-like wrinklings, with the few large cells, are plainly to be seen, wonderfully

preserved. This lava evidently was very pasty, and the flows have a contour and surface that reminds one very strongly of the recent lava flows of the Sandwich Islands. I have no doubt that the eruption was of the same quiet kind, and the lava a basalt of the same character as that now poured forth from Kilauea.

The structure of these lava flows can be well seen at the localities known as Great Lobster Cove, Break Heart Point and Taylor's Nose. At the latter a fissure forming a cave by the sliding of one side of the mass, with the subsequent sea action, admits us into the interior of these flows, where the same structure of a series of pasty flows—one above the other—is to be seen.

The present outline of these slopes was formed by the thick viscid basaltic lavas, the original surfaces of the flows being still preserved. While indeed other flows may have been removed, one thing is certain, the present surface is now the surface of a flow. Not a trace of glaciation could be found, but the fiord-like character of this region seems to be mainly due to the building up of steep slopes by lava, the intrusion of eruptive masses and the jointing and faulting, with or without a change of the relative position of the sea and land. The whole region bordering on Notre Dame Bay has clearly been the theater of tremendous volcanic activity which in part at least is of later date than the graptolite shales. The absence of glacial phenomena is very striking to one used to New England; Signal Head, by the city of St. John's, being the only locality in which any such phenomena were observed by me.

One of the projecting rounded knobs of the above mentioned lava was procured. This is a fine-grained greenish-gray rock weathering brown and holding small porphyritically inclosed crystals of feldspar. The section (860)* is composed of an earthy gray groundmass holding porphyritic feldspars. The groundmass is made up of a dirty gray fibrous and granular mass, formed undoubtedly from the alteration of a glassy or globulitic base, and inclosing numerous minute ledge-formed basaltic plagioclase crystals. Some viriditic or greenish micaceous material of a secondary nature occurs, as well as traces of ferruginous granules derived from the alteration of magnetite grains. A few augite grains together with some pseudomorphs after olivine were observed. Excepting the secondary changes, this lava is in microscopic structure strikingly like that from the eruptions of Kilauea in 1872, the microscopic characters thus supporting the field observations. This rock is here regarded as formed from a viscous glassy lava—a basalt, whose

* The numbers correspond to the numbers of rocks in the Whitney Lithological Collection in the Museum of Comparative Zoölogy.

present difference from that of Hawaii is due solely to secondary changes since eruption. In its present state it would be called by most lithologists a melaphyr.

The same lava flows were seen on the south side of Lawrence Harbor on the main land. The specimen procured is somewhat more altered than the preceding, and contains calcite and dark delessite (?) amygdules, besides some pyrite. In the section the base is more decomposed and the feldspars are in part obliterated by the secondary spherulitic structure induced by alteration, which is here much more strongly marked than in No. 860. A number of pseudomorphs after augite, etc., are composed of quartz grains implanted on the walls and an interior portion of dirty green delessite. One amygdule of the delessite was seen which showed a dirty green aggregately polarizing mass crossed by a band of lighter green fibrously polarizing delessite (?). Delessite and viridite are irregularly scattered through the section and one pseudomorph of the latter after olivine was seen.

Melaphyr (Dikes).

On South West Point of Exploits Burnt Island a number of dark melaphyr dikes were observed. A specimen (865) from one about two feet in width, cutting the diabase and striking north and south, is a brownish black rock with yellowish brown spots of decomposition, which resemble decomposed feldspars. It weathers brown and cellular and contains grains and crystals of augite, magnetite and pyrite.

The brownish section is composed of a dense groundmass of augite microlites, biotite and magnetite, holding larger augites, greenish viriditic and dolomitic pseudomorphs after olivine, etc. The augite is mostly in yellowish and brownish elongated crystals, containing magnetite inclusions. The biotite is in brown irregular scales, while considerable calcite and a greenish fibrous spherulitic product were seen (delessite?). The general structure of the rock is very similar to many nephelite basalts, but no trace of feldspar was seen nor anything that could be referred to nephelite. The augite and magnetite alone, of the mineral constituents observed, are regarded as original. All the rest appear to be secondary. The rock effervesces with hydrochloric acid but does not gelatinize, showing that the olivine is entirely altered and that nephelite is not now present. This rock is regarded as an old and altered basalt.

Diabase.

The diabase (881) of Hoskin's Harbor, Thwart Island, occurs in a dike about twenty feet wide, running north and south, and cutting argillite. The rock is a gray finely crystalline

diabase containing pyrites, and weathering brownish gray. Section greenish gray, and appears to have been originally composed of divergent feldspar (plagioclase) with the interspaces filled by irregular grains and dissected masses of augite, magnetite, olivine (?), etc. At present the augite is in general only slightly altered, and is of a brownish color or nearly colorless. It is much fissured, sometimes cloudy and at others altered to a greenish chloritic material. The feldspars are for the most part kaolinized and altered, although retaining distinct evidence of their triclinic character.

Of secondary products there occur, among others, considerable chloritic material, some calcite, quartz, microlites, and actinolite fibers. A few greenish masses were seen that may be pseudomorphs of olivine granules, their forms and polarization characters being the same as those of such pseudomorphs seen in other basaltic rocks.

At Tom Hall's harbor, on Exploits Burnt Island, the main rock is a diabase cut by numerous later diabase dikes. The former (850) is a grayish green crystalline rock showing feldspar and pyrite crystals. Under the microscope it is seen to be composed of divergent basaltic plagioclase with the interspaces filled by magnetite and secondary viridite, chlorite, and epidote. The feldspars are somewhat altered, although polarizing with brilliant colors, and contain epidote granules, chlorite scales, and colorless needles resembling tremolite. The chlorite is dichroic, varying from a pale yellowish to greenish. The epidote is in granules varying from a yellowish to a colorless state. This rock was found to be more or less jointed and fissured, and where it was more broken than usual segregations of copper and iron pyrites existed. These limited and worthless masses had been taken as evidence of extensive deposits of chalcopyrite and considerable money expended in prospecting, etc.

A short distance from this locality at Green Island Cove, some prospecting had been done in a similar diabase rock containing some copper and iron pyrites. In the section the general structure of this (853) rock is seen to be the same as that of the preceding (850) but it has suffered further alteration so that the feldspars are considerably changed. Some calcite occurs in the rock.

This rock is also cut by diabase dikes, one of which (851) is a greenish gray finely crystalline rock but more compact than the preceding and somewhat fresher. In the section it is seen to be only a little less altered than No. 853. Considerable calcite and some greenish secondary hornblende was observed, otherwise the two sections are nearly the same.

Another diabase occurring near No. 850, and perhaps a portion of the same mass, is more coarsely crystalline with pinkish feldspars. At the western point enclosing Sargent's Cove, a coarse-grained basaltic rock (867) occurs cut by fine-grained diabase dikes (866).

The rock on the north side of Betts Cove is a diabase, which on the weathered surfaces shows spherulitic concretions of impure epidotic material. These concretions are seen to be a superficial phenomenon, for they diminish in size and amount in the interior.

No. 903 from Little Bay Mine, is a greenish rock flecked by pinkish spots of alteration origin. Under the microscope the greenish section is seen to be from a rock entirely altered, a natural condition when it is realized that the dike from which it came forms the line about which is arranged the ore of the mine. The section is composed of an irregular confused granular aggregation of secondary epidote, chlorite, green and white mica, quartz, feldspar, microlites, etc. The epidote and chloritic and micaceous material predominate. This rock is similar to some specimens in the collection from Sonora, Tuolumne County, California.

Diorite.

At Sargent's Cove a coarse grained old basaltic rock, No. 867, occurs. This is of a dark greenish color and composed macroscopically chiefly of black hornblendic crystals. The section is composed of a confused mass of secondary greenish and brownish fibers and crystals of hornblende, magnetite, talc-like masses, carbonates, pseudomorphs apparently after olivine, which seem to be mainly dolomitic, mica, etc. From many observations that the writer has made on rocks of like character he is led to regard all these coarse dioritic rocks as formed from the alteration both of gabbros and coarse-grained diabases.

Porodite.

On the mainland at Needle Cove, Exploits Bay, the rock is a coarse (877, 878) and fine (879, 880) fragmental rock of dark greenish, gray color, and composed of eruptive detritus—probably a volcanic ash. It contains pyrite and calcite. The specimens are composed principally of melaphyr material with the secondary products: chlorite, some colorless pyroxene, quartz, etc. Magnetite and decomposed feldspar occur. Much of the melaphyr was evidently a cellular, glassy basalt and in some cases is still black and opaque. If it were not that the cells are filled with secondary materials it would be difficult sometimes to distinguish these melaphyr grains from some of the

tertiary basalts of California. In most of the fragments the fine basaltic feldspars retain their forms.

These rocks belong to the old tufaceous products to which I have given the name of porodite,* but since the basaltic material predominates in them they are placed under that species.

Andesite (?)

Minette, or Mica Trap.

At Great Lobster Cove a "mica trap" was found, running north 40° east, and thirty-two inches in width. No. 855 came from the edge of this dike and is a dark, brownish gray rock, weathering rusty brown and containing crystals and plates of black mica and hornblende needles, with some pyrite and quartz. The brownish gray section is composed of a yellowish and grayish white groundmass holding augite, hornblende, magnetite, and biotite crystals. The rock is much altered, but the augite is indigenous, and in relatively large porphyritically inclosed crystals, having a well-marked cleavage. The central portion of the larger augite is of the usual pale yellowish color, but the exterior is of a pale pinkish-brown tint, observed so commonly in the European augites. Connected with this alteration of color is seen in some crystals an immense number of straight hair-like microlites. The color and the microlites both appear to be associated with the alteration. The augite is both in short, thick forms, and in elongated crystals and microlites, and has more the character of the augite of the andesites than that of the basalts. The smaller crystals and microlites are usually of the pale pinkish-brown color.

The hornblende is in both short and elongated crystals, with a dichroism varying from light yellowish brown to dark brown. It is almost identical in general appearance with the mica, but is optically different, while the cleavage of the hornblende is nearly wanting. Both minerals are abundant. The groundmass is composed of a pale yellowish or grayish mass, mostly isotropic, but sometimes polarizing feebly; and containing numerous microlites, granules, etc. It also holds calcite and greenish fibrous spherulitic delessite (?), which sometimes forms concretionary masses with centers of calcite.

No. 856 came also from the edge of the dike, but is more decomposed. The section is essentially the same as the preceding, but there are more fibrous products of decomposition and more calcite. The augite is less in amount and the crystals sometimes have a greenish dichroic center. Owing to the greater alteration, the groundmass here shows generally some polarization.

*l. c. p. 280.

No. 857, from the central portion of the dike contains well-developed biotite and augite crystals, with calcite and quartz grains. Some of the biotite crystals inclose portions of the rock mass in the center. The section is composed of a dense groundmass of augite, biotite and hornblende microlites with calcite, magnetite, and some grayish white binding material generally isotropic. The augites sometimes have greenish centers with yellowish external portions. One form, composed of veins of viriditic material inclosing dolomite, resembled an olivine pseudomorph. Considerable greenish fibrous spherulitic material, like delessite, occurs associated with calcite.

No. 858 is from the center of the dike and is essentially the same as the preceding.

Of the ingredients of this dike, the augite and magnetite alone of the minerals observed are regarded as original materials, all the rest are considered to be secondary or alteration products.

No. 855 effervesces strongly with hydrochloric acid, but does not gelatinize.

The difficult question with this mica trap is, what was the original state of the rock. The characters now remaining indicate that it was once a basalt or an andesite, its present condition being due to alteration since its eruption. The structure of the porphyritic augites, with their relation to the groundmass, indicate an altered andesite, while in many respects the rock resembles the melaphyr, No. 865, previously described. The preponderance of its original characters appears to be of an andesite type, and it is with doubt classed under that species.

In a similar manner from their structure and pseudomorphs, the minette (5015) from Himmelsfürst, near Freiberg in Saxony, and that from Weinheim in Baden (5080) appear to be altered and old andesites.

Porphyrite.

A brownish gray rock from Wells's Cove, Exploits Bay, cuts the argillite and is composed of a brownish gray granular groundmass with greenish spots, and segregations of calcite. In the section it is seen to be composed of altered plagioclase and orthoclase, with ferrite, quartz, calcite and chlorite forming a groundmass which incloses larger, altered porphyritic feldspar crystals. The plagioclastic forms appear to have predominated, although the alteration is so great the decision is doubtful. In the present condition the mass is chiefly composed of secondary ferrite granules, quartz, calcite and chlorite, with microlites, etc. It is difficult to say to what species—basalt, andesite, or trachyte—this rock belonged, but it most closely resembles the andesites.

Argillite.

The western part of Exploits Burnt Island shows an indurated argillite (864), and jasper (862), associated with a fine-grained conglomerate or coarse sandstone (863). The latter is seen, under the microscope, to be composed of fragments of feldspar, quartz, magnetite, melaphyr, etc., cemented by a matrix. In the hand specimen, jaspery and argillite fragments were observed. The matrix is now altered mainly to a chloritic mass containing a few quartz grains, feldspars, etc. The chloritic material is mostly isotropic and in some places shows a structure that might readily be taken for a fluidal one. This seems to be owing to the crystallization of the chloritic scales in vein-like deposits. The feldspathic fragments form the chief portion of the section and are much altered now, showing aggregate polarization, and having a fibrous kaolinized and talc-like structure. The quartz is in irregular fissured grains containing stone and fluid cavities bearing moving bubbles. The melaphyr is much altered, retaining only its structure. While this rock is composed mostly of ordinary detritus it may in part be from volcanic ashes.

An argillite (868) coming from the southwest part of the island is greatly indurated, breaks with a conchoidal fracture, and is composed of a grayish green groundmass holding quartz grains. Under the microscope this is seen to be a distinctly clastic rock like the preceding, and while in the main fine-grained it contained some larger fragments like No. 863.

It is now composed of greenish micaceous scales, quartz, feldspar, ferrite, microlites, etc. The quartz and feldspar (orthoclase) are both a fragmental and a secondary production, probably through water action. A few broken crystals resembling zircons were seen.

At Easter Cove, Exploits Bay (on the main land, near Muddy Hole), the argillite is much indurated, although less so than the preceding. The strata here show a varying dip from 30° to 90° (usually 60° to 80°) to the southward. The strata are much contorted and bent, and in one place a general northward dip was seen. A section of the argillite No. 869 closely resembles No. 868, being of similar character, but finer grained and of lighter color. It is traversed by veins of quartz and calcite. Near Welles' Cove, Exploits Bay, the argillite is black, laminated like a shale, and cut by dikes of diabase and porphyrite.

On the west side of Lawrence Harbor the shaly argillite stands nearly vertical and carries graptolites.

Jasper.

Where the lava flows or intrusive masses come in contact with the argillite the latter is often baked to a dark brick-red jaspery mass, irregularly fissured, traversed by minute quartz and calcite veins and breaking with a conchoidal fracture. One section (862) is composed of a reddish brown groundmass of ferrite globules mingled with secondary quartz and holding numerous globular and irregular patches of quartz. These segregations oftentimes form the principal portion of the section. Veins filled with quartz and calcite with some epidote traverse the section. Some chlorite, microlite, margarites, trichites and fluid inclusions occur in the quartz veins. No. 859 is a denser rock and contains more epidote, both in the veins and in rounded segregations. These jasper rocks have been quite extensively acted upon apparently by thermal waters, and were found to pass into distinguishable argillites at a short distance from the point of contact with the eruptive rocks. Both specimens were found to be infusible* before the blowpipe, although little fused globules appeared in the case of No. 859, owing to the epidote in it. Observations made by myself indicate that rocks ordinarily called jasper are formed by the induration of argillite by eruptive action, by chemical deposition, and by eruption—the second form only being true jasper.

THE ORE DEPOSITS.

At the time of my visit the lower levels of the Betts Cove Mine were filled with water. The mining had been done in an irregular manner, taking the ore wherever it could be found; thus the walls not having sufficient support had broken away on one side and fallen in. All the work then doing was in the taking out of ground that had been left in the upper workings.

The mine is in mixed argillite, chlorite schist, and diabase. The ore band runs east and west, and is cut by north and south dikes, of which there were said to be ten in the mine. The dikes seen were all diabase. Over one-half of the adjacent country rock is eruptive, but all the ore of importance is found in the schistose portions formed from the altered argillite and diabase. The ore is of secondary deposition, being a segregation in the broken fissured altered portions of the rock, and, judging from the ore seen and the workings, must have occurred in immense irregular masses. The ore is chalcopyrite mixed with pyrite, quartz, etc. The foot wall is formed by diabase.

The upper portion of Little Bay Mine is worked in chlorite schist impregnated with chalcopyrite. The whole is longitudi-

*Fusibility of the Amorphous Varieties of Quartz. Proc. Bost. Soc. Nat. Hist., 1877, xix, 238.

nally cut by a dike (No. 903) parallel with which run three bands of chalcopyrite which lie near the dike. In depth these three bands pass into one, varying from six inches to four feet in thickness, and the mixed chlorite schist and ore of the upper portion of the mine is wanting. The character of the workings and the geological structure seen in this mine show that this deposit was an immense lenticular mass of schist impregnated with impure chalcopyrite, the widest portion being on the surface and gradually narrowing in depth. The ore from this locality is mixed chalcopyrite and pyrite with quartz, schist, etc.

The Roberts Arm Mine is worked on two veins from two to four feet wide in the eruptive diabase. The veins are composed of quartz carrying very compact chalcopyrite. While the veins widen in depth they do not appear to improve in quantity or quality of the ore. The sides of the veins are indistinct and firmly attached to the country rock, thus partaking more the character of a gash than a fissure vein. The same kind of veinstone and ore has been sunk upon at a locality known as "Sandy Vein" about one-fourth of a mile distant.

At Lawrence Harbor the old basaltic lava had been prospected for ore and considerable work done, but the vein is simply a gash vein containing quartz carrying pyrite. A vein in the shaly argillite had been worked to some extent, but showed only some impure graphite with quartz.

At Hoskins Harbor, Thwart Island, Exploits Bay, a grayish black, somewhat indurated, nearly vertical argillite (882), is cut by a north and south dike of diabase (881), about twenty feet in width. This diabase is cut by a few gash veins of pyrite, quartz, and calcite containing a little chalcopyrite and malachite. These veins had been worked to some extent by persons not acquainted with their limited occurrence. The mode of occurrence of the copper ores in northern Newfoundland, taken with the geological structure of the country, indicates the following as their origin. The argillaceous and schistose rocks have been cut through and through by dikes and irregular masses of eruptive basaltic rocks. During the time of this eruptive activity, after the chief portion of this basalt had been extravasated, the action of percolating thermal waters on the eruptive rock and its fissured and broken adjoining sedimentary rock, led to the concentration and deposition of the copper, iron, and quartz in the places in which they are found.* The copper is here thought to have been brought up from below finely disseminated through the basaltic material and later concentrated by the percolating waters.

*See Bull. Mus. Comp. Zool., 1880, vii, 123–131; Proc. Bost. Soc. Nat. Hist., 1880, xxi, 91–103.

The productive masses of ore seen were found in connection with these old basaltic masses, but generally deposited in the adjacent schist or in decomposed portions of the diabase, for the boundary lines of the eruptive masses afforded the conditions necessary for the precipitation of the copper sulphide. The eruptive masses are as a rule too massive and compact to afford suitable places for the deposition of the ores, thus the prospector is naturally to search for them in the schists adjacent to the large eruptive masses. The deposits thus occurring are irregular segregations or impregnations of varying bulk, but they do not promise in any one locality long continued mining. It is perhaps best to do as seems to have been done up to the time of my visit; work the mines in an irregular slovenly manner, stripping out the ore masses wherever found, so far as safety permits, with the idea of abandoning the mines as soon as the chief portion of the ore is extracted. The Betts Cove and Little Bay Mines at the time of my visit presented to me the appearance of having been well worked out, although considerable ore yet remained, particularly in the latter.

One prevalent error regarding the rocks of this country ought to be corrected, i. e. the belief that the ores are associated with serpentine. No serpentine was seen by me at any of the points touched between Twillingate and Betts Cove except one small bowlder at the latter place. I am informed it exists in that vicinity, and Mr. Murray assured me it occurs at Tilt Cove. The ores, so far as seen, occurred in diabase and schists; hence the statements, so industriously circulated in almost every article relating to the Newfoundland copper deposits, regarding the relation of the ores to serpentine are entirely incorrect in the districts seen by me.

In closing, I desire to express my warm thanks to the veteran director of the Geological Survey of Newfoundland, Alexander Murray, C.M.G., for his many kind favors during my stay in St. John's, and my regrets that ill health has compelled him to resign the post he has so long held.

Cambridge, Mass., March 22d, 1884.

ART. XV.—*The Origin of Bitumens;* by S. F. PECKHAM, A.M.*

SPECULATION regarding the origin of bitumens has been pursued during the last half century along several quite different lines of investigation, and has been influenced by several different classes of experience. Generally speaking, these lines fall into three different classes and embrace those who regard bitumen as a product of chemical action, those who regard it as indigenous to the rocks in which it is found, and those who regard bitumen as a distillate produced by natural causes.

The argument for a purely chemical origin of petroleum was first brought to the serious attention of scientific men by Berthelot in 1866. He found that when carbonic acid or the earthy carbonates were brought to react with alkali metals at a high temperature, oily fluids were formed similar to or identical with those found in petroleum. Byasson produced the same fluids by causing steam, carbonic acid and iron to react; and Cloez produced them by the reaction of boiling water upon a carbide of manganese. The chemists of this school assume that the alkali metals, iron at a white heat and spiegeleisen with other raw chemical reagents, exist in the interior of the earth, and that petroleum is formed by the reaction upon them of carbonic acid in water which everywhere infiltrates the terrestrial crust. These chemical theories are supported by great names, and are based upon very elaborate researches, but they require the assumption of operations nowhere witnessed in nature or known to technology.

M. Coquand, who has written so fully upon the occurrence of bitumen in Albania and Roumania, and C. H. Hitchcock, have both advocated the theory that all forms of bitumen are produced by a chemical reaction in which marsh gas is converted into more condensed hydro-carbons, appearing as fluid, viscous and solid bitumens. In so far as this theory expresses the fact that maltha represents an intermediate stage in the transformation of petroleum into asphaltum and recognizes the relation existing between marsh gas and the petroleum compounds, it is entitled to consideration; but in the chemical processes of nature, complex organic compounds pass to simpler forms, of which operation, marsh gas, like asphaltum, is a resultant and never the crude material upon which decomposing forces act.

The opinion that petroleum is indigenous to the rocks in which it is found has been maintained with great vigor by T. Sterry Hunt and J. P. Lesley, both of whom have based

* Abstract of Chapter V of the Monograph on Petroleum, prepared for the Tenth Census of the United States.

their views upon extended observations in Canada, West Virginia and Kentucky. At several localities in Canada, Dr. Hunt has observed the marine fossils of the Trenton limestone filled with petroleum in which it was hermetically sealed, and he regards the petroleum that saturates portions of the Niagara limestone near Chicago, as indigenous to that formation. In a recent letter, J. M. Safford informs me that in the limestone rocks that form the Silurian basin of middle Tennessee it is not uncommon to meet with geode cavities lined with calcite crystals and containing more or less petroleum. I am also informed by Edward Orton that the Clinton limestone of Ohio, lying over the whole northern border of the Cincinnati anticlinal, contains petroleum in small quantities. In J. P. Lesley's paper on "the existence of petroleum in the eastern coal field of Kentucky," he has shown that in Johnson County, Kentucky, the great Carboniferous conglomerate is saturated with petroleum at horizons now above the level of the water in the streams that intersect the country. He thinks the Coal-measure plants contributed to the formation of the petroleum and observes that "the specific gravities of the oil, decreasing with the increase of the depth, is a fact which shows conclusively that a chronic evaporation or distillation of the whole mass of oil in the crust of the earth (within reasonable reach of the surface), has always been and is still going on, converting the animal and plant remains into light oils, the light oils into heavy oils, the heavy oils into asphalt or albertite, the process being accompanied at every stage with the liberation of gas." In his introduction to Report III, of the Second Geological Survey of Pennsylvania, he remarks "that it (petroleum) is in some way connected with the vastly abundant accumulations of Paleozoic sea-weeds, the marks of which are so infinitely numerous in the rocks, and with the infinitude of corralloid sea animals, the skeletons of which make up a large part of the limestone formations which lie several thousand feet beneath the Venango oil-sand group, scarcely admits of dispute, but the exact process of its manufacture, of its transfer, and of its storage in the gravel beds, is utterly unknown." It is evident that in these later statements Professor Lesley expresses his opinion respecting the changes that convert the original petroleum content of the rocks into the different varieties of petroleum now met with, although in his earlier papers and particularly in the one first quoted, Lesley has been one of the most conspicuous advocates of the opinion that the petroleum of the Appalachian system is indigenous to the rocks in which it is found. The observations of Wall in Trinidad appear to establish beyond a doubt that the bitumen of that locality has been and is being produced

from a peculiar decomposition of woody fibre. Bright and Prestwich both regard the petroleum of England as indigenous in the limestones and shales, and the testimony of E. W. Binney is conclusive as to the production of petroleum from the decomposition of peat on Down Holland moss. J. D. Whitney has suggested that the infusorial remains so abundant in the sedimentary rocks of Southern California, are the original source of the petroleum occurring in them.*

I think no doubt can be entertained that in certain localities of limited extent petroleum and other forms of bitumen are indigenous to the rocks in which they occur.

As early as 1804 Humboldt observed a petroleum spring issuing from metamorphic rocks in the bay of Cumana and expressed the opinion that it was "the effect of distillation at an immense depth." . . . . Dr. J. S. Newberry and the late Professor E. B. Andrews have both called attention to the similar character of the distillates obtained from bituminous coals and shales and petroleum and suggested that petroleum is a product of distillation by natural processes and at low temperatures. Daubrée has in "Études sur le Métamorphisme" very fully discussed the relation of bituminous substances to metamorphism and has proved by experiment the adequacy of such an origin for all forms of bitumen.

The studies which I have made upon petroleum, extending now over a period of more than twenty years, lead me to the conclusion that as yet very little is known regarding the chemical geology of petroleum. No one has studied the chemical properties of different varieties of petroleum in relation to their geological occurrence in any effective manner; it would therefore be extremely rash for any one to dogmatize with reference to the origin of bitumens. I am, however, led to state the conclusions that a careful survey of our available knowledge of the subject has enabled me to reach. I am convinced that all bitumens have, in their present condition, originally been derived from animal or vegetable remains, but that the manner of their derivation has not been uniform. I should, therefore, exclude all chemical theories as impossible or unnecessary. There remains the hypothesis that bitumen is indigenous in the rocks in which it is found and that which regards all bitumens as distillates. Whichever of these hypotheses be chosen, the modifying fact must be accepted that there are four kinds of bitumen:

1st. Those bitumens that form asphaltum and do not contain paraffine.

2d. Those bitumens that do not form asphaltum and contain paraffine.

* Dr. J. S. Newberry has lately erroneously attributed this theory to myself. Ann. N. Y. Acad. Sci., ii, No. 9.

3d. Those bitumens that form asphaltum and contain paraffine.

4th. Solid bitumens that were originally solid when cold or at ordinary temperatures.

The first class includes the bitumens of California and Texas. They are doubtless indigenous in the shales from which they issue. It is also probable that some of the bitumens of Asia belong to this class.

I have described the conditions under which bitumens occur on the Pacific coast of southern California in great detail in the reports that I have made to the Geological Survey of that State. The forms of bitumen that are found there are almost infinite in gradation, from fluid petroleum to solid asphaltum. In Ventura county the petroleum is primarily held in strata of shale, from which it issues as petroleum or maltha, according as the shales have been brought into contact with the atmosphere. The asphaltum is produced by further exposure after the bitumen has reached the surface. These shales are interstratified with sandstones of enormous thickness, but I nowhere observed the petroleum saturating them, although it sometimes escaped from crevices in the sandstone, nor was the bitumen held in crevices of large size nor under a high pressure of gas; the disturbed and broken condition of the strata, folded at high angles, precluding such a possibility.

The topography and stratigraphy of the coast ranges of Santa Barbara, Ventura and Los Angeles counties are very complex. The Santa Barbara islands, off the coast bordering these counties, are volcanic islands, where lava-flows are described as having formed cascades over cliffs of sedimentary rocks as they descended into the sea. On the mainland no lava appears to have reached the surface, although along the stage road from San Buena Ventura to Los Angeles, between Las Posas and Simi, on an eroded plateau surrounded by low mountains, fragments of scoria are scattered over the ground. The Coast Ranges here appear to have been produced by parallel folds, each successively higher, by which enormously thick beds of sandstone, interstratified with shale, were thrust up at an angle of about 70°, producing parallel anticlinals, which were subsequently eroded in such a manner as in many instances to produce valleys and plateaus where the sandstones were broken through to the softer shales beneath. This is the case with the western extremity of that fold which, commencing at Point Conception, extends eastward to Mount San Bernardino. West of the Sespé the sandstone crest has been completely removed and the shales cut away until, at the Rincon, east of Santa Barbara, the erosion reaches the sea-level, and beyond, to the westward, the upturned edges of the shale

form the bed of the ocean. The narrow plain on which Santa Barbara stands, lying between the Santa Iñez mountains and the sea, consists of Pliocene and Quaternary sands and gravels resting upon the eroded shales. East of the Rincon and Mount Hoar, the table-lands lying in the trough of the anticlinal gradually ascend until at the Sespé the sandstone caps the high mountain to the eastward. This range, occasionally broken by transverse cañons, extends to near the headwaters of the Santa Clara River near the Solidad Pass, where it becomes merged in the San Rafael range. Between Point Conception and Point Rincon, where a stratum of sand occurs saturated with maltha, that substance has arisen and floated on the sea, attracting the notice of travelers ever since that coast was known to Europeans. At Point Rincon, where the anticlinal recedes from the coast, maltha rises and saturates the Quaternary sands. As the ascending plateau passes farther inland we find a line of outcrop of the bituminous strata on the east and west sides of the basin in the line of hills east of Mount Hoar and in the Santa Iñez mountains. East of the San Buena Ventura River, the local synclinal fold in the shale forming the Azufre mountain gives four lines of bituminous outcrop. In the cañons of the Sespé, wherever the bituminous strata have been reached by erosion, tar springs and asphalt beds are the result. The deeply-eroded narrow valleys which cover the country east of Santa Barbara and south of the Coast Range present in the distance of a few miles the greatest lithological variations, and expose the bituminous strata under the greatest diversity of conditions. For this reason we meet here every possible form of bitumen in every possible degree of admixture, with soil and organic remains.

The second class of bitumens includes the petroleums of New York, Pennsylvania, Ohio and West Virginia. These oils are undoubtedly distillates from vegetable remains, the proof of which seems overwhelming. Pennsylvania petroleum was examined in 1865 by Warren and Storer in this country, and in 1863 by Pelouze and Cahours in France. They found the lighter portion to consist of certain series of hydrocarbons identical with those obtained in the destructive distillation of coal, bituminous shales and wood when the operation was conducted at low temperatures. Messrs. Warren and Storer also discovered that the same series of hydrocarbons could be obtained by distilling a lime soap prepared from fish oil. The experience of technology has shown that if coals or pyroschists are distilled at the lowest possible temperature, particularly in the presence of steam, a black, tarry distillate is obtained along with a considerable quantity of marsh gas, and very volatile liquids that cannot be condensed except at low temperatures.

If these distillates are re-distilled, the second distillate may be divided into several different materials, beginning with marsh-gas and ending with very dense oils heavily charged with paraffine. It is impossible to conduct this primary or secondary distillation without producing marsh-gas, but the amount of this gas and the density of the fluid produced will depend on the temperature at which the distillation is carried on and the rapidity of the process. The use of superheated steam is found to increase the quantity of distillate and to prevent overheating, and the formation of other hydrocarbons than those belonging to the paraffine series.

The section compiled by Mr. J. F. Carll, for Report III of the Reports of the Second Geological Survey of Pennsylvania, shows the Devonian shales above the Corniferous limestone and below the Bradford third oil-sand 1600 feet in thickness. This shale outcrops along lake Erie, between Buffalo, New York, and Cleveland, Ohio, where it is for the most part the surface rock in the neighborhood of Erie and southward to Union City, Pennsylvania. No one can examine this shale without noticing the immense quantity of fucoidal remains that it contains. N. S. Shaler estimates the Devonian black shale of Kentucky to cover 18,000 square miles at an average depth of 100 feet, and to yield on distillation fifteen per cent of fluid distillate. It is not necessary to follow him in his calculations of the enormous bulk of this distillate as represented in barrels; the important point in this connection, is that it is a very persistent formation, being revealed by borings over a very wide area, and doubtless extending eastward beyond the boundaries of Kentucky, beneath the coal-measures which contain the petroleum.

If, however, the Devonian black shales are inadequate both on account of extent and position as a source of supply, we may descend still lower in the geological series to the Nashville limestone and other Silurian rocks that underlie that region. Professor Safford writes, in a recent letter, "The Lower Silurian limestone in the basin of middle Tennessee is about 1000 feet thick. Including the Upper Silurian limestones, the whole thickness of the limestones, in which are found occasionally little pockets or geodes and cavities of petroleum, is not far from 1200 feet. The most of the petroleum has been found in the upper part (the Nashville) of the Lower Silurian, as, for example, the larger cavities near or on the upper Cumberland River, in the neighborhood of the Kentucky line, both within Kentucky and Tennessee." These limestones underlie the whole petroleum region of southeastern Kentucky and middle Tennessee.

The objection urged by Professor Andrews, that the coals in

the measures of Ohio and West Virginia, among which these coals occur, have lost nothing of their volatile content, is without force here. Professor Shaler objects that—"The condition of the beds that lie below the black shale in the Cincinnati group or in the Niagara section shows that there has been no great invasion of heat since the beds were deposited. Clays, which change greatly under a heat of 1000° Fahr., are apparently exactly as they were left by the sea, and beds retain their marine salts just as when they were deposited. Any great access of temperature in this deposit of the Ohio shale would have been attended by an almost equal rise of temperature in the coal-beds which lie within a few hundred feet above; but these coal-beds are free from any evidences of distillation or consequences of heat. We have already seen reasons for supposing an erosion of some 3000 or 4000 feet of strata from this section; if we could reimpose this section we should probably bring up the temperature of these rocks by the rise of the isogeothermals or lines of equal temperature about 60°. . . . We are not able to suppose that the accumulation of strata would have elevated the temperature above the boiling point of water. The hypothesis which may be found to account for the formation of this coal-oil must take into consideration the impossibility of its generation at another point and its removal to this set of beds, and the impossibility of supposing that it has been in any way the result of high temperatures."

The range of temperature between "the boiling-point of water" and "1000° Fahr.," which is here allowed, is ample for all purposes of explanation.

Mendeljeff objects that—"the sandstones impregnated with petroleum, have never exhibited the carbonized remains of organisms. In general, petroleum and carbon are never found simultaneously."

These three objections—first, that the supply of organic matter is inadequate; second, that there are no evidences of heat action upon the rocks holding the oil; third, that there are no residues of fixed carbon observed in the rocks holding the oil—are the objections which have appeared to satisfy those who do not accept the hypothesis that regards petroleum as a distillate. I think the first has been already answered; the second and third I shall now examine.

It is not the effects of heat, as represented by volcanic action, that have produced petroleum, although in one notable instance Silvestri found paraffine and other constituents of petroleum in the lava of Etna. A comparison of the analyses of the gaseous emanations of volcanoes with those of gas and petroleum springs shows that the former consist mainly of car-

bonic acid and nitrogen, while the latter consist mainly of marsh-gas. Bitumens are not the product of the high temperatures and violent action of volcanoes, but of the slow and gentle changes at low temperatures due to metamorphic action upon strata buried at immense depths.

The extent of the Paleozoic formations of the Mississippi valley, and the general conformation of the bottom of the ancient seas, has been fully described by Professor James Hall.* He says: "In all the lower Silurian limestones we trace the outcrop to the west and northwest, from the base of the Appalachians in New York or in Canada, to the Mississippi River, and thence still in the same northwesterly direction. . . . Instead of finding the lower Helderberg (Upper Silurian), strata in lines parallel with those of the preceding rocks, the relative direction of the main accumulation and the principal line of exposures is diagonally across the others. . . . The line of outcrop and of accumulation has been from northeast to southwest, and they occur in great force far to the northeast in Gaspé, on the Gulf of St. Lawrence. . . . The greatest accumulation of materials in the period of the Hamilton, Portage and Chemung groups (Lower and Middle Devonian), lies in the direction of the Appalachian chain. . . . In Gaspé there are 7000 feet of strata, . . . while in western New York the whole together would not exceed 3000 feet. We have, therefore, the clearest evidence that the strata thin out in a westerly direction. . . . In considering the distribution of the masses of the formations which we have here described, we find that the greatest accumulations have been along the direction of the Appalachian chain. The material thus transported would be distributed precisely as in an ocean traversed by a current like our present Gulf Stream; and in the gradual motion of the waters during that period, to the west and southwest, the finer material would be spread out in gradually diminished quantities, till finally the deposit from that source must cease altogether. . . . I have long since shown that . . . the portion of the Appalachians known as the Green Mountain range is composed of altered sediments of Silurian age. . . . The evidences in regard to the White Mountains, to a great extent are of newer age than those of the Green Mountains, or Devonian and Carboniferous. . . . The statements of Sir William Logan in regard to the great accumulation of strata in the peninsula of Gaspé, together with the observations of Professor Rogers in the Appalachians of Pennsylvania, lead to the inevitable conclusion that the sediments of this age must everywhere contribute largely to the matter forming the metamorphic portion of the Appalachian chain as well as to the non-metamorphic zone immediately on the west of it."

* Nat. Hist. N. Y. Paleontology, iii, 45–60.

It is not necessary here to discuss the nature or origin of metamorphic action. It is sufficient for our purpose to know that from the Upper Silurian to the close of the Carboniferous period the currents of the primeval ocean were transporting sediments from northeast to southwest, sorting them into gravel, sand and clay, forming gravel bars and great sand beds beneath the ripples, and clay banks in still waters, burying vast accumulations of sea weeds and sea animals far beneath the surface. The alteration due to the combined action of heat, steam and pressure, that involved the formations of the Appalachian system, from Point Gaspé in Canada, to Lookout Mountain, in Tennessee, including the Carboniferous and earlier strata, distorting and folding them, converting the coal into anthracite and the clays into crystalline schists, along their eastern border, could not have ceased to act westward along an arbitrary line, but must have gradually died out farther and farther from the surface. The great beds of shale and limestone containing fucoids, animal remains and even indigenous petroleum, must have been invaded by this heat action to a greater or less degree, and that "chronic evaporation" of Professor Lesley must have been the inevitable consequence.

Too little is known about petroleum at this time to enable any one to explain all the phenomena attending the occurrence of petroleum, upon any hypothesis; but it seems to me that the different varieties of petroleum, from Franklin dark oil near the surface, to Bradford and Clarendon amber oil far beneath the surface, are the products of fractional distillation; and one of the strongest proofs of this hypothesis is found in the large content of paraffine in the Bradford oil under the enormous pressure to which it is subjected. So, too, the great pools of oil in southern Kentucky are without doubt distilled from the geode cavities beneath and concentrated in fissures of the rocks near the surface.

If this hypothesis, which embraces all of the facts that have thus far come within my knowledge, really represents the operations of nature, then we must seek the evidences of heat action at a depth far below the unaltered rocks in which the petroleum is now stored. We ought to expect to find the coal in its normal condition. We should not expect to find the carbonized remains of organisms in the rocks containing the petroleum. As the metamorphic action took place subsequent to the Carboniferous era, we should expect to find the porous sandstones of that formation in certain localities saturated with petroleum. Moreover, we should expect to find these Coal-measure sandstones and conglomerates on the western border of the heated area, where the thinning out of the deposits

brought down the Coal-measures nearer the Devonian shales and Silurian limestones, first saturated with petroleum, and then, through ages of repose, gradually cut down by erosion into the cañons of Johnson county, Kentucky, and exhibiting all of the phenomena described by Professor Lesley.

The inadequacy of the scattered remains of plants in the Coal-measure sandstones as a source of the petroleum that saturates them is shown by the following calculation, which was made by Professor Lesley for another purpose: "Should the Mississippi send down one tree a minute for a century, with an average length of forty feet and a foot in diameter, and these be laid together side by side at the bottom of the sea in a single stratum, they would cover only a space of 200 acres. Were it possible, which it is not, to compress and crystallize these lignites into a stratum six feet thick, they might then constitute a coal bed covering twenty acres. All the forests of the Mississippi valley could not furnish to the sea from their river spoils during a hundred thousand years one of the anthracite coal beds of Schuylkill county."*

According to M. Coquand, the petroleum of Wallachia is in the inferior Tertiary with mud volcanoes and rock salt; the "Flysch à Fucoids" is the horizon in Moldavia, corresponding to the formation in which it occurs in the Crimea, Transylvania, Galicia, Volterra of Tuscany, the Appennines, Sicily, and Algeria, being everywhere rich in fucoids. The conclusions reached by geologists regarding the occurrence of petroleum in Galicia show that the central core of the Carpathians consists of metamorphic rocks, on the flanks of which lie the members of the Cretaceous and Tertiary formations, consisting of limestones, sandstones and shales. The latter are for the most part rich in organic matter both vegetable and animal, such as fossil fucoids and fish. In East Galicia and Bukowina heavy beds of black bituminous shales are particularly noticeable. These formations lie in folds, the petroleum, which belongs to the third class, occurring under the arches of anticlinals rather than in the troughs of synclinals.

The facts to be obtained regarding the occurrence of bitumen in Asia are very few. It appears to be generally concluded that the formation from which the petroleum in the neighborhood of the Caucasus arises is Tertiary; but so far as I can ascertain it issues rather from erratic beds of sand in superficial clays than from any well-defined formation. Lartet appears to regard the bitumen of the Dead Sea as of volcanic origin. The petroleum of Java lies in the Tertiary beneath alluvium, which flanks the volcanic core of the island.

Granting that the petroleum of the Niagara limestone at

* A Manual of Coal and its Topography, p. 49.

Chicago is indigenous, the invasion of that limestone by steam under high pressure would cause the petroleum to accumulate in any rock lying above, porous or fissured sufficiently to receive it. The mingling of oils that produce asphaltum and those that contain paraffine, and the occurrence of paraffine in large masses in porous strata filled with the remains of fucoids and marine animals that flank the core of crystalline schists in Roumania and Galicia, offers the strongest support to this hypothesis. The fact that the eruptive rocks of Lake Superior and the metamorphic rocks farther east prevail to such an extent that that vast inland sea has been supposed to be the crater of an extinct volcanic lake lends the strongest support to an hypothesis that regards the vast accumulations of petroleum in Western Canada as due to invasion of strata on the borders of this heat center, in which the petroleum is indigenous, by a sufficiently elevated temperature to cause its distillation.

Mud volcanoes and hot springs, it appears to me, are properly regarded as the phenomena attending the gradual subsidence of metamorphic action in the crust of a cooling earth. The accompanying petroleum or maltha is but the accident of such phenomena when strata containing organic remains are still invaded at a great depth by a temperature sufficiently elevated to effect the distillation of their organic contents. Gas springs may own the same origin, or the gas may escape from deep-seated reservoirs, the product of a distillation long since completed.

Solid bitumens of the fourth class occur in great variety.

The universal distribution of bituminous material in rocks was noticed in 1823 by the Hon. Geo. Knox. The occurrence of disseminated bitumen in metamorphic rocks, supposed to be Laurentian, at Nullaberg, in West Sweden, has been described; also in the lower Silurian of south Scotland; in trap near New Haven, Connecticut; and in northern New Jersey, all of which are manifestly the results of the action of heat upon the organic matter in stratified rocks. The occurrence of bituminous limestones in France and in the valley of the Rhone has been attributed almost unanimously by French geologists to the action of igneous or metamorphic agencies.

There remain the phenomena attending the occurrence of large veins of solid bitumen in Cuba, West Virginia, New Brunswick and elsewhere, for which no adequate explanation has been proposed that does not regard them as the product of distillation from deep-seated strata, which has been projected into a fissure formed by the sudden rupture of the earth's crust. Dr. R. C. Taylor examined the vein which occurs in metamorphic rocks near Havana, and concluded that, "it was evidently originally an irregular open fissure, terminating upward in a wedge-like form, having various branches, all of which have

been subsequently filled with carbonaceous matter, as if injected from below, and that not by slow degrees, but suddenly and at once." No hint is given by Dr. Taylor respecting the age of these rocks, as at the time he wrote (1837) the relation between metamorphic and sedimentary rocks had not been established. There is little doubt, however, that the veins in New Brunswick and in West Virginia originated at nearly the same time and subsequently to the Carboniferous era. It is certain that subsequent to that era a great convulsion caused an upheaval that in collapse produced the White Oak anticlinal in West Virginia, very near the southern end of which occurs the vein of Grahamite, cutting the horizontal sandstones of the Coal-measures vertically. Those who mined the vein declare that the material must have welled up from beneath into the fissure the instant it was formed. Numerous fragments of the wall-rock were found imbedded in the asphaltum twelve to fifteen feet below the cavities from which they fell, with all of their edges and angles sharp and exactly fitting each other. Curious curved lines, resembling those produced when a stone is dropped into mortar, are found on these horses, suggesting the probability that the horses fell into a plastic mass that rolled upon them, producing lines of unequal pressure and adhesion that remain after the asphaltum has cleaved from the horses or enclosing walls. Moreover, neither the walls of porous sandstone, nor the horses, have absorbed the bitumen to the thickness of paper. The significance of these facts was more forcibly impressed upon my mind when I found among a suite of specimens from the Albertite vein of New Brunswick a piece of the inclosing shale, marked with the mineral in forms almost identical with those observed on the sandstone horses in West Virginia.*

In 1869 I made the origin of albertite and allied substances the subject of a paper in which I compared the observations made in New Brunswick and West Virginia with my own observations of a vein on the coast of California, which is exposed west of Santa Barbara, and stands vertical, cutting the Pliocene and recent sands. With this vein are associated lenticular masses extending horizontally, from which a sort of talus projects vertically into the sands beneath.† Similar deposits are described by M. Coquand as occurring in Albania. He mentions in connection with the bituminous strata, solfataras and mud volcanoes both active and extinct, with which was associated more or less fluid maltha, which was at first very liquid, but soon became syrupy and was finally added to the accumulations of the bituminous cone. From his

* Very carefully drawn illustrations of these stones have been introduced in the original monograph. † This Journal, II, xlviii, 362.

statement it appears that solid bitumen occurs in great abundance, filling variously formed cavities which in no case penetrates the roof above the mass, "but was evidently injected from below." Here the maltha accompanies the water of springs from deep-seated strata often in close proximity to active or extinct volcanic action of the mild forms observed as solfataras, mud volcanoes or salses. The great similarity in the occurrence of intruded Tertiary bitumens in Albania and California is very remarkable.

It should be borne in mind that while this subject is one of speculation, pure and simple, it is a subject that has its valuable consideration outside the domain of scientific enquiry or curiosity, as affecting the sources and duration of supplies of petroleum, its profitable development and commercial permanence. If petroleum is the product of a purely chemical process, we should not expect to find Paleozoic petroleums of a composition corresponding with the simple animal and vegetable organisms that flourished at that period, and Tertiary petroleums containing nitrogen, unstable and corresponding with the decomposition products of more highly organized beings; but we should expect to find a general uniformity in the character of the substance, wherever found, all over the earth. The advocates of the chemical theory affirm that they provide for a process the conditions of which are perpetually renewed. It is thus continuous and at present active. On the contrary, if petroleum is the product of metamorphism, its generation is coexistent only with that of metamorphic action, an action which we have no reason to believe has been prevalent on a large scale during the recent period. If we accept this hypothesis, the generation of petroleum must be considered as practically ended.

ART. XVI.—*On the Measurement of rapidly alternating Electric Currents with the Galvanometer;** by L. M. CHEESMAN.

Preliminary.—In view of the frequent use made of rapidly alternating electric currents in determining the resistance of liquids, etc., a more delicate instrument than the one we now have for such determinations has become a desideratum. At Professor von Helmholtz's instigation I endeavored some time ago to employ the deflections arising from electromagnetic action for this purpose. The following pages give a brief account of the experiments made in this direction.

* From a paper by L. M. Cheesman, read before the Royal Academy of Sciences of Prussia by Professor von Helmholtz, July 13, 1882.

After a number of experiments on the action of alternating currents on soft iron, with rather unsatisfactory results, a phenomenon first carefully studied by Poggendorff* was chosen as a basis for further study. The phenomenon referred to can be described as follows: if rapidly alternating electric currents are passed through the coil of an ordinary galvanometer, placed so that the plane of the windings makes an angle with the magnetic meridian, a deflection takes place in such a direction as to still further increase the angle between the plane of windings and the needle; in other words, the needle strives to take up a position at right angles to the plane of the windings. Poggendorff explained this by referring the phenomenon to the action of the alternating currents on the temporary magnetism induced by them in the needle of the galvanometer, the resultant action of the currents on the permanent magnetism of the needle being zero.

To examine this explanation more closely, suppose rapidly alternating currents, each of equal intensity, to be sent through the coil of a galvanometer placed so that the needle makes an angle of about 45° with the plane of the windings. The magnetic effect of the coil on the needle can be divided into two components, one parallel to the magnetic axis of the needle, producing no rotation but tending to magnetize it positively or negatively according to the direction of the current passing at the moment; a second at right angles to the magnetic axis tending to produce rotation in the needle. The effect of two consecutive currents on the needle, the first positive and the second negative, would evidently be as follows; the first with the intensity $(+i)$ increases the magnetic moment (M) already present in the needle by some quantity (m), so that there exists a moment of rotation proportional to $i(M+m)$; similarly the second current with the intensity $(-i)$ decreases the magnetic moment (M) of the needle by the same quantity (m), so that the moment of rotation in this case is proportional to $-i(M-m)$. The moment of rotation therefore arising from the two consecutive currents is proportional to $i(M+m)-i(M-m)=2im$, independent therefore of the permanent magnetism of the needle. By a similar course of reasoning it will be readily seen that the moment of rotation due to the horizontal intensity (T) of the earth's magnetism tending to draw the needle back into the meridian is independent of the induced magnetic moments and proportional to 2TM.

Preliminary experiments to ascertain whether the phenomenon above described could be employed for the desired purpose were made with an ordinary galvanometer placed so that the plane of the windings made an angle of about 45°

* Pogg. Ann., xlv, 1838.

with the magnetic meridian; the alternating currents were obtained from a small induction apparatus of the du Bois-Raymond form. The following points were to be considered: first, whether the apparatus was sufficiently sensitive, and second, whether for the same intensity of current the needle always had a determined position, which it would not have had did the currents employed in any way alter the permanent magnetism of the needle. The results of the experiments in both of the above particulars were sufficiently favorable to warrant the hope that after a few changes a practical instrument based on the above principle could be made.

Description of Apparatus.—The following is the form of the instrument finally adopted. The circular coils and metal parts connected with the damper of a galvanometer of Edelmann's form were removed and in their stead were placed two coils, each having 2200 turns of silk-covered copper wire (diameter $0{\cdot}25^{mm}$). The play-room for the magnet was a right-angled parallelopipedon, 11^{mm} in height, 61^{mm} in breadth and length; the resistance of the two coils together amounted to 474 ohms. The magnet consisted of eleven hard steel wires (diameter $1{\cdot}6^{mm}$) securely fastened together and magnetized to saturation by a large number of impulses of the magnetizing force. As the deflection of the needle, other things remaining the same, is greater as the product of its permanent magnetic moment and the horizontal intensity of the earth's magnetism is less, the sensitiveness can be heightened by diminishing the value of this product. In this instrument, as noticed above, the moment of rotation from the currents being independent of the permanent magnetic moment, the reduction of either the permanent moment or the horizontal intensity would have the result of increasing the delicacy. Should the permanent magnetic moment be reduced by using unsaturated magnets there would be danger that the magnetic condition of the needle would not remain constant when acted upon by the alternating currents; the same result can, however, evidently be attained without this disadvantage by fastening saturated magnets together, some of them having their poles reversed; the usual method of diminishing the value of the horizontal intensity by approaching permanent magnets is, however, to be preferred.

Magnetization of the Needle.—In regard to the galvanometer needle it is to be noticed that the trustworthiness of the results obtained with the above instrument depends on its not being altered, except temporarily, by the action of the alternating currents. The effect of a magnetizing force on a magnet is, however, in general both of a temporary and a permanent character; were induction in magnets always accompanied by this permanent change, the construction of a trustworthy in-

strument based on the above principles would evidently be impossible. Fromme* has shown that this is not always the case, and from his experiments he draws the following conclusions: first, that when steel is magnetized by a large number of impulses of the magnetizing force the magnetic moment approaches a fixed limit for every intensity of the magnetizing force as the number of impulses increases; second, that after the limiting magnetic moment for a force P has been reached, forces between 0 and P are incapable of effecting any permanent change in the magnetism of the steel, and the temporary magnetic moment induced by such forces is proportional to the intensity of the force acting.

These laws would seem to require a more special investigation than has yet been made regarding several particulars before their unqualified acceptance; that however the currents did not cause any sensible permanent alteration in the magnetism of the needle employed in my experiments the following experiments I think conclusively show. A permanent change in the magnetic condition of the needle might consist either in a change in the direction of the magnetic axis or a change in the permanent magnetic moment. Had the former occurred by the action of the currents it would evidently have shown itself by irregularities in the position of rest of the needle after the current had been acting; a graphic representation of the positions of rest of the needle in a series of experiments extending over the greater part of a day, the current being closed from time to time, showed, however, no such irregularities. Had the second possibility occurred, that is, had the permanent magnetic moment of the needle been altered by the action of the currents, it would evidently have caused a change in the delicacy of the instrument; this point was carefully tested by repeated comparisons of the delicacy of the instrument with that of a Weber's electro-dynamometer in the same circuit, the results were such as to give no ground for assuming that the delicacy of the instrument underwent any perceptible alteration.

Law of Deflection.—According to the article of Fromme, already cited, the induced magnetism in a magnet which has been magnetized by a large number of impulses of the magnetizing force, increases proportionally with the force, for all forces between zero and P. As mentioned above, some further investigation is required in regard to this point before its application to the case before us, and I hope to make this the subject of a future communication. Assuming, however, that the proportionality exists, the square of the intensity (i) of the currents will be for small deflections approximately proportional to the tangent of the angle of deflection (φ), when the

* Pogg. Ann. Ergänzungsband, vii, 1876.

axis of the windings of the galvanometer makes an angle of 45° with the magnetic meridian. For suppose the instrument placed so that the axis of the windings makes an angle (α) with the magnetic meridian and that the needle has experienced a deflection φ from the meridian by the alternating currents; the conditions of equilibrium will evidently be,

$$MT \sin\varphi = iM'f(R) \sin(\alpha-\varphi),$$

M denoting the permanent magnetic moment,
M′ the induced magnetic moment,
T the horizontal intensity of the earth's magnetism,
i the intensity of the alternating currents, and
$f(R)$ a function depending on the number and form of the windings, etc.

M′ can be replaced by $if(R)\cos(\alpha-\varphi)$, whence we obtain,

$$i^2 = c\,\frac{\sin\varphi}{\sin 2(\alpha-\varphi)}, \quad c = 2.\frac{MT}{[f(R)]^2}.$$

For the special case $\alpha=45°$, $\frac{\sin\varphi}{\sin 2(\alpha-\varphi)}$ differs but 0·2 per cent from $\tan\varphi$, when $\varphi=3°$.

Delicacy.—The following table gives an idea of the delicacy of the above instrument and its variation with the time of vibration of the needle as altered by reducing the value of the horizontal intensity of the earth's magnetism. The first column gives the time of vibration of the needle, the second the quotient obtained by dividing the deflection observed on the galvanometer by that of a Weber's* electro-dynamometer in the same circuit, so that the same intensity of current acted in each case, both deflections of course being reduced to the same scale distance. The time of vibration of the dynamometer spool was 20 sec.

Time of vibration.	Quotient of the deflections.
8·3″	0·7
10·	1·1
16·	2·6
22·	4·3

So that for equal times of vibration the galvanometer had considerably greater delicacy, although the Weber instrument had over 1800 more turns of wire than the galvanometer.

In conclusion, I should state that a number of determinations of resistances by the method of substitution with alternating currents were made with the above instrument with very satisfactory results.

* Instrument made by Leyser. Number of windings of the stationary spool, 1860; resistance, 152 ohms; number of windings of the movable spool, 4380; resistance, 205 ohms.

ART. XVII.—*On some Specimens of Nickel Ore from Nevada;* by SPENCER B. NEWBERRY.

WITHIN the past year have appeared frequent references to the occurrence of nickel ores in Churchill Co., Nevada, all seeming to indicate that a very valuable source of supply of nickel has come to light. Through the kindness of Chas. Bell, Esq., of Sacramento, one of the discoverers of the deposit, I was able to obtain a complete series of specimens from the different levels so far opened, namely, the 10 ft., 45 ft., and 60 ft. level, and the 80 ft. drift. The specimens amount in all to about 30 pounds in weight, and are by far the finest masses of nickel ore I have ever seen.

The sample from the greatest depth (80 ft.), consists of nearly pure *niccolite*, which in the 60 ft. and 45 ft. specimens show the progress of oxidation and hydration, this action appearing more complete as the surface is approached. The specimen from the 10 ft. level (nearly eight pounds in weight), consists entirely of the hydrated arseniate, or *annabergite*, with but a small amount of impurity. The analysis of a sample of the entire mass gave:

NiO	33·71 per cent.
As_2O_5	36·44 "
H_2O	24·77 "

The remaining five per cent represents small quantities of iron, copper, and insoluble residue, with traces of cobalt.

In his letter accompanying the specimens, Mr. Bell gives the following description of the deposit:

"The property is situated in Cottonwood Campus, Churchill Co., Nevada. The ledge is perfectly incased, running 6,000 ft. N.E. and S.W., when it pitches into the Carson Desert and is lost. The ledge is thirty feet between walls, the mineral lying in veins, of which there are thirteen in all, each from ten to thirty-five inches wide. The gangue which separates these veins of ore is in layers from four to eight inches wide, and consists of silica, iron, lime and magnesia. The same character of minerals extends throughout the whole length of the lead."

In view of the extraordinary purity and richness of the ore, there can be little doubt that if future developments should bear out the present indications outlined in Mr. Bell's description, the mines of Nevada will eventually become a very prominent source of the world's supply of this valuable metal.

Laboratory of Cornell University, June 30, 1884.

Art. XVIII.—*Gorges and Waterfalls;* by William Morris Davis.

Narrow gorges and abrupt waterfalls are seldom found in old countries of flat rocks and moderate elevation. For a gorge opens wider and wider in the course of its natural growth, and becomes a broad valley in its maturity and old age; a waterfall decreases in height as it is worn farther and farther back, until at last it remains only as a faint ripple in the almost uniform down-grade of its stream. Kentucky, Ohio, Western Pennsylvania and New York are old land surfaces of this kind, and their valleys are broadly open, unless bordered by excessively hard rocks, and waterfalls seldom break the even descent of their watercourses, except where the great glacial accident of prehistoric times has disturbed their flow. But within the glaciated area, a stream may, even in the middle part of its course, suddenly enter a narrow gorge, a true cañon in miniature, and leap down precipitous falls, while its fellows in the same neighborhood and in the same set of rocks have the usual open valley slopes of regular descent. Not unfrequently these gorges are in rocks of very moderate hardness.

It will probably be discovered, when all our falls and ravines are studied, that by far the greater number of them result from the local displacement of streams from their old open channels by blockades of glacial drift, or less commonly by temporary obstruction from the glacial sheet itself. This important generalization has often been alluded to in geological reports, as will be shown below, but it as yet finds no place in our text-books, although glacial drift is as frequently an essential factor in the production of our gorges and falls as in the making of our lakes and ponds.

It is of course to be understood that falls and gorges are produced in other ways also. The greatest gorge of the world, the Colorado Cañon, was formed by rapid downward erosion following the rapid elevation of the plateau in which it is cut; but in such a case, all the streams of the region flow in cañons of more or less pronounced form, and the cleft-like appearance of the valley is not exceptional. Waterfalls are also found in countries quite free from glacial action; but such countries are generally high, and the cascade, although old, is not yet old enough to have worn its hard bench-rock back into a smooth, gentle slope. The headwater streams that leap down the ravines in the massive mountains of southeastern Kentucky give examples of this kind. Falls are also sometimes, but very seldom, produced by faults; the cascades of the Yosemite are most plausibly of this kind, and some of the falls in Norway

must have the same origin, if Professor Kjerulf's theory of the making of the fjords by dislocation prove correct. But all these examples are in regions quite unlike those of the moderate relief and inconsiderable dislocation that are here to be considered.

The following examples will serve to illustrate the importance of the connection between drift and gorges.

Professor James Hall called attention many years ago to the numerous gorges of western New York.* They are nowhere better shown than along the course of the Genesee. Above Portage there is a broad, alluvial valley, the bottom of an old lake; thence to Mt. Morris the stream flows through a meandering gorge over three hundred feet deep, leaping down several falls, shut in by steep, rocky banks free from drift. Not far to one side, the abandoned preglacial channel may be traced by the heavy drift deposits, which when sounded by wells or borings are found to have a very significant thickness. Lateral streams enter the new channel in deep gorges; or, if small, plunge into it in cascades, giving excellent sections of the upper Devonian strata. Nearly every stream flowing from the south over rocks of this age in western New York presents the same features in a greater or less degree. A hundred examples can be cited where there is demonstrative proof of the recent origin of the gorges. Farther north, from Mt. Morris to Rochester, the Genesee again follows an ancient open valley, wandering over alluvial meadows and seldom touching rocky strata; but from Rochester to Lake Ontario it follows a second gorge, the upper end of which is well seen from the trains of the New York Central Railroad as they cross the bridge just above the falls. The abandoned valley is probably a little farther east.

The gorge of the Niagara River is the largest single piece of post-glacial erosion this side of the Mississippi. Just how much of the gorge has been cut since the final disappearance of the ice-sheet cannot now be said with certainty; but it can hardly be questioned that the greater part of this deep channel is of comparatively recent origin, and that it had its beginning when the former open drainage of the valley of Lake Erie was held back, probably by drift obstruction, so as to form the lake and force its overflow to choose a new line of escape; and to this accident we owe our great waterfall.† The numerous glens and ravines down which rapid streams flow into the north and

* Geology of New York, IV District, 1843, 371, 422. Here and beyond, extracts are sometimes given almost word for word from the authors named, but quotation marks are omitted.

† The evidence for this origin of Lake Erie and Niagara is summarized in my paper on the Classification of Lake Basins, Bost. Soc. Nat. Hist. Proc., xxi, 1882, 362. A recent paper by G. F. Wright on "The Niagara Gorge as a Chronometer," is in the Bibliotheca Sacra, April, 1884.—See also p. 32 of this volume.

south lakes of the western arm of New York must frequently or always have a similar origin; notably the gorge below Taghannock Falls on the west side of Cayuga lake, and Watkins Glen at the head of Seneca lake. Trenton Falls and Ausable Chasm, farther east, most likely come under the same class, but so far as the author knows there are no descriptions of them sufficiently detailed to make the matter sure. Local studies of these interesting spots would lead to valuable results. The creek that joins the Mohawk at Canajoharie flows from an open, flat, drift-covered country into a deep, narrow, rocky gorge. Schoharie Creek has throughout the greater part of its course opened a terraced valley in the drift-filling of its old channel; but a few miles below Gilboa it abruptly enters and as suddenly leaves a rocky chasm, a few hundred yards long and fifty or more feet deep. Here it has evidently lost its former line of flow, and cut its new bed in the rocky slope of its old trough. Rondout Creek does the same about two miles above its junction with the Hudson.

Several of Professor Newberry's writings* call attention to the old buried channels in Ohio and the numerous gorges resulting from turning old streams into new courses. Rocky River, for example, which enters Lake Erie seven miles west of Cleveland, follows an open valley strewn with drift in the upper part of its course, but when two miles above its mouth it enters a narrow trough with rocky walls and floor and follows it to the lake.† A little west of its present point of discharge its ancient channel is seen, now filled with clay to an unknown depth below the present surface of the lake. Grand river, in Lake county, is of similar character.‡ At the falls near Akron, the Cuyahoga follows a narrow gorge and in two miles descends two hundred and twenty feet in a series of cascades. In the same neighborhood there is plentiful drift and numerous small lakes among the gravel hills. Many lakelets have been filled with peat, but nearly one hundred still remain within twenty miles of Akron. From the falls to Cleveland, where the Cuyahoga enters Lake Erie, the stream follows the general line of its old course, but flows on heavy drift clays which bury the rocky bottom of the channel two hundred feet deep.§ The rapids at the Sault Ste. Marie in the outlet of Lake Superior, and of the Ohio at Louisville, are thought by Professor Newberry to mark new channels.

A few miles west of Chillicothe, in central Ohio, there is a small stream called Paint creek, which flows for the greater part of its course through an open, fruitful valley enclosed by

* Proceedings Bost. Soc. Nat. Hist., ix, 1862–63, 42; Annals N. Y. Lyceum Nat. Hist., ix, 1870, 1; Amer. Naturalist, iv, 1870–71, 193; Geology of Ohio, i, 1872, 42, ii, 1874, 12.

† Geol. Ohio, i, 174. ‡ Id., i, 511. § Id., i, 201, etc.

hills of moderate slope about five hundred feet high on either side. Suddenly and without apparent cause the stream turns from this broad trough and enters a narrow gorge with steep rocky walls not less than three hundred feet high, in which it continues for about five miles on a circuitous course, until it regains the broad valley three miles below its point of departure. The abruptness of the change from the old to the new course, and the striking difference between the gentle, drift-covered and cultivated slopes of the former and the bare, precipitous walls and rocky bed of the latter make this case an excellent example for our consideration. There must have been some strong obstacle placed in the old matured channel to cause the creek to leave a course so well suited to its wants; to turn from what it had been patiently at work preparing for unnumbered thousands of years, and cut out a new passage through the hills; and Professor Orton, who first, some ten years ago, gave a detailed description of this notable locality,* concludes that the obstacle was the ice of the glacial sheet that had its margin, during its farthest southern advance, in this district. The upper waters of the creek must have been held back by the ice, aided by the drift, and risen behind them into a lake, whose level is marked by heavy terraces of stratified drift, until a line of overflow was found around the barrier; and along this overflow the gorge has been cut out. From the report of the same geologist on Clarke County,† we learn that its rocky floor beneath the drift, wherever disclosed by streams, railroad cuts, quarries, or borings, is extremely irregular, showing the existence of an old buried drainage system, the minor features of which have been almost obliterated by the drift deposits that deeply cover nearly all the surface and greatly reduce its relief. The old channels were choked with sand and clay brought there by the ice and water of the Glacial period; and when those strange conditions ended and the modern or postglacial period began, the waters, gathering again from the rain and springs, had to make new choice of channels. The lines of the old streams were selected in the greatest number of cases, for though their rocky troughs were buried deep out of sight, the drift mantle was still as a rule lower there than on the adjoining hills. But sometimes the streams found their best escape along new lines of flow; there they have abandoned the old channels and wrought out new ones, and these constitute most of the narrow gorges in the cliff rock that make so notable a feature in the scenery of this region.

The Falls of St. Anthony in the Mississippi at Minneapolis and the gorge below them are shown by Professor N. H. Win-

* Geological Survey of Ohio, ii, 1874, 653.
† Geol. Ohio, i, 460.

chell* to result from a displacement of the river from its older and wider channel that ran west of the present course from a point just above Minneapolis, down to the wide channel of the Minnesota River, three miles above Fort Snelling. The Mississippi, forced by an ice or a drift blockade to depart from its old channel, rose till it reached the level of the limestone bluffs of its eastern bank; a lake was thus formed from which abundant deposits of fine brick-clay remain. The overflow ran across country about eight miles to Fort Snelling, where the old channel was again taken; in plunging over the limestone bluffs, the waters gave birth to the Falls of St. Anthony. Since that time, the falls have receded to their present position, leaving a narrow valley below them; and from the records of early exploration Professor Winchell has computed that this recession of eight miles has occupied somewhat less than nine thousand years. The Falls of Minnehaha are in a side ravine branching from this new channel of the Mississippi a little over a mile above the original site of the Falls of St. Anthony at Fort Snelling. Their ravine was therefore begun about a thousand years later than the Mississippi channel, and being the work of a much smaller stream, their recession is only about one mile from the front of the new Mississippi bluffs. Several still smaller falls along the bluffs have the same origin. The dalles of the St. Croix and the rapids of St. Louis rivers, also in Minnesota, may probably be referred to postglacial erosion, but explicit statements of their origin are not to be found. The southern peninsula of Michigan must also furnish many examples of newly made falls and gorges, for the streams there are described as generally flowing on the drift, but sometimes cutting down into the rock.

Professor I. C. White, of the Geological Survey of Pennsylvania, has given several excellent descriptions of gorges. Wallenpaupack Creek, dividing Wayne and Pike counties in the northeastern part of the State, is one of the most striking examples of its class. In preglacial times, it had carved out a wide and deep channel in Catskill strata from the Pocono plateau northeastward to its junction with the Lackawaxen, having a descent of four hundred feet in eleven miles without any notable falls so far as can be discovered. During the Glacial period, the lower end of the channel was filled with drift to a depth of three hundred feet, so that, where the ice melted away, the re-established drainage found a shorter cut and lower passage to the Lackawaxen about three miles above its former mouth. For ten miles above the obstruction, the 'Paupack meanders through a broad, flat, swampy valley, the bottom of a recently extinct lake, with a fall of only half a foot in a mile:

* Geol. Minn., 4th Ann. Report, 1876, 178.

it then enters a narrow gorge, and in one mile descends two hundred and sixty feet in a succession of cascades and rapids. Blooming Grove Creek, a few miles east of the 'Paupack, is another example of the same kind. Again, Shohola Creek, a tributary of the Delaware, once entered that river about half a mile below its present mouth through a channel now deeply buried; the creek has cut down a new passage through the rocky cliffs bordering the river, thus making the great gorge at Shohola Glen since the close of the Glacial period. The falls of the Raymondskill and the Sawkill, near the angle of Pennsylvania between New York and New Jersey, are both due to new courses around obstructions in drift-filled valleys. The Delaware, where these streams join it, flows southwest along the outcrop of the soft Marcellus Shale, bounded on the southeast by the back of a ridge held up by the Oriskany sandstone, and on the northwest by the bluffs of the Hamilton group. In long preglacial time, the streams from the northwest had cut deep gaps through the line of bluffs, and had insignificant falls if any; now they plunge over the Hamilton cliffs. The evidence of this change is perfectly clear and satisfactory. In the case of the Sawkill, there is a point back of the bluffs about three miles from the Delaware, where a narrow ridge of drift, only twenty-five feet higher than the present channel, turns the stream away from a low, deep, drift-filled valley to the east, cut down far lower than the head of the falls; and yet nothing flows along this old valley but a trifling stream fed by a few springs. The conclusion that it was once the course of the Sawkill is irresistible, for the Sawkill brings all the water from the back country needed to accomplish the excavation of so deep and broad a trough. The drift-filling where the stream is turned to its new course toward the falls is estimated to be three hundred feet thick. The explanation of the new course of the Raymondskill is equally conclusive. Professor White suggests that the several other high cascades over the Hamilton bluffs along the Delaware in this part of its course, such as those on Adam's, Dingman, Hornbeck and Little Bushkill Creeks owe their origin to a diversion from their old channels by drift-dams; but no detailed study of their topography was made.*

Other illustrations of our topic described by the same author,† are found on the highlands northwest of Wyoming Valley: Harvey's lake is a long, narrow, irregularly shaped body of water, occupying an old buried valley to a depth of ninety feet. The old outlet is closed by drift; the new line of overflow has already lowered the lake over one hundred feet by

* Geol. Penn., G6, Pike and Munroe Counties, 1882, 57–62.

† Geol. Penn., G7, Wyoming, etc. Counties, 1883, 171, 131, 133.

cutting a narrow, gorge-like channel, with bare outcropping rocks free from drift for one hundred and twenty-five feet above the lake level. Crooked Lake, also in Wyoming county but on the other side of the deep valley of the Susquehanna, has the same origin; the old valley below the lake is now without a stream, for the overflow has turned to one side, first running with gentle slope over drift deposits; then descending one hundred and ten feet in a narrow gorge over a series of rocky cascades. Here it joins Buttermilk Creek, the lower course of which has been entirely changed by glacial deposits. Vast heaps of drift are piled up in the old channel about the mouth of the ancient stream, so that its modern representative is turned aside to plunge over the cliffs of Catskill rocks into the valley of the Susquehanna. In the deep, narrow gorge that has thus been formed, the stream falls eighty feet in several cascades in a horizontal distance of two hundred yards. The old valley can be traced nearly clogged with drift heaps; and the evidence of the change in the stream's course is said to be singularly clear and conclusive.

Other post-glacial valleys, with steep rocky walls and very little drift are described by Mr. Carll in western Pennsylvania, while the old valleys are broad and deeply filled with heavy drift deposits.*

The most appreciative description that I have found of the relation between drift obstructions and river gorges is in Mr. J. Geikie's 'Great Ice Age.' Nothing can be more striking—this author writes—than the sudden and complete change of scenery that ensues upon the passage of a stream from its new into its old channel. In the former the water frets and fumes between lofty walls of rock, which, seen from below, appear to rise almost vertically from the river's bed. In such a deep, narrow gorge the stream may continue to flow for miles, when of a sudden the precipitous cliffs abruptly terminate, and the water then escapes into a broad vale, with long sloping banks of stony clay, sand and gravel. The burial of old valleys is especially common in districts where they stretch across the advance of the ice; the gorges of the Avon and the Calder, branches of the Clyde, are thus explained as post-glacial cuts, to one side of the drift-filled, pre-glacial channels.†

Mr. A. Geikie writes of one of the most remarkable gorges in Scotland,‡ that of the Mouse water, in the district of the Cartland crags, near Lanark. The stream descending from the shady ravines of Cleghorn flows smoothly for half a mile through an old valley still choked up with bowlder-clay. This

* Geol. Penn., III, Oil Regions, 1880, 347.

† Great Ice Age, 1877, 133.

‡ On the Glacial Drift of Scotland, Trans. Geol. Soc. Glasgow, i, pt. 2, 1863, 51.

valley runs on below the house of Baronald, but instead of keeping this, which was probably its ancient course, prior to bowlder-clay times, the river turns abruptly round in front of Baronald, and plunges into the old Red Sandstone, through which it has worked a dizzy ravine, some 200 feet or more in depth, whose western precipices are known as the Cartland crags. Emerging from this well-nigh twilight gorge, the river rejoins its old channel and soon loses itself in the Clyde. Some other examples are named.

That this clear description was not generally appreciated is shown in a later account of the same gorge, where although it is recognized as of aqueous origin, wonder is expressed that the downward erosion should have so greatly exceeded the lateral cutting.*

In view of these many examples, it seems fair to regard the falls and gorges of our Northern States as the result of glaciation, and to group them with the rolling surface of the drift, dotted over with ponds and lakes, as signs of an immature drainage system. The long pre-glacial time of land-existence gave our rivers east of the Mississippi ample opportunity to perfect their courses; to destroy all the lakes that must have existed in great numbers while the land was rising and the mountains were growing; to wear back all the falls until they disappeared, or until they retreated to the higher regions of the little headwater streams; and to widen all the valley slopes to a well opened angle, except where especially hard rocks persist in holding the streams within narrow channels. Then came the ice invasion, bringing altogether new conditions over the Northern States; hills and ledges were rounded off and valleys were widened and deepened; the rubbish was strewn over the country in a most irregular way, thin at one place, thicker at another; and although in part carried by subglacial streams, it was chiefly scraped along by the ice itself. Its transportation was under control of forces quite unlike those that prevailed during pre-glacial times, and hence its deposition was largely independent of the glacial stream courses. At the end of the Glacial period, while the streams well south of the ice-limits were still persevering in their perfect ways, those on the glaciated area often found that much of their previous work was lost and had to be done over again. As fast as the ice melted back, the rivers took possession of the country, and while the larger and stronger ones in nearly all cases found escape along their accustomed channels, many of the smaller streams were quite bewildered and lost their way among the heaps and sheets of drift that masked their old valleys, and had to settle down as best they might on the lowest ground they could find.

* Dougall, Falls of Clyde, Trans. Geol. Soc. Glasgow, iii, 51, 1871.

They were restrained in lakes and ponds behind drift barriers, and were turned aside from a life of comparative ease in their well-prepared old channels to an age of hard work in active rock cutting—and here we now see them, just accommodated to their new lines of life.

An old stream, having its volume, its load of silt and its slope so related to one another that its channel is eroded with extreme slowness, comes as near to a condition of stability as streams can. It has, after a long age of endeavor, at last adapted itself to its environment, and has very little tendency to variation. But any change in its condition of life sets it at work again, seeking another attitude of satisfied equilibrium. If, for example, the land across which an elderly, conservative stream flows, is elevated with comparative suddenness, the stream finds its point of discharge lowered, and thereupon sets to work, with all the strength gathered from its whole drainage basin, to cut the lower end of its valley down to the level of quiet water again; and the deep cutting will work its way backward up stream, requiring a readjustment to the new slope up to the head of every little creek and rivulet of its basin. For a time, during the change, the deepening of the channel will go on faster than the widening, and the old flat valley will be marked by a gorge-like trough along its median line. Thousands of valleys of this compound form may be seen in the streams of the Rocky Mountain region. Indeed it was in that region that this important relation of the cutting power of a stream to its "base-level of erosion" was first well appreciated; and its illustration includes some of the finest work of our government geologists. On the other hand, if the land were depressed, the level of dead water would advance above the former mouth of the stream, and the submerged part of the valley would be slowly buried in delta deposits.

Both of these changes are effected at once by the drift blockades that glacial action has thrown so plentifully across our northern valleys. Above the obstruction, the stream becomes a lake, and is deadened into inactivity. Silt from the headwaters settles here and in time will fill the lake and form a marsh or meadow. On the lower side of the obstruction, the stream finds a strong descent, and there begins the rapid deepening of the channel chosen for escape. If this overflow channel be upon the drift barrier itself, and the down-slope below it be pronounced, then the lake is drained before much thickness of silt accumulates upon its bottom. In this way, many of our marshy meadows have been formed. If the slope of the outlet be gentle, or if a moderate down-cutting will make it so, then the lake has a much longer life; and this is the case of the great number of our smaller lakes and ponds that still

remain. Finally, if the overflow be turned aside from the old valley way, and find its line of escape leading over steep sloping rocks, the gorges, cascades and waterfalls will mark its line and give character to the new channel. Even in soft, shaly rocks, the down-cutting in such cases is much faster than the lateral widening; and in the relatively early stages of development the gorges will be narrow and steep-walled. We now are in this stage, as is abundantly shown by the examples already quoted. We have to thank the old ice-sheet for our picturesque gorges as well as for our pleasing lakes.

It has been suggested that the gorges are in many cases the work of subglacial streams during the presence of the ice, instead of the effect of open water cutting in later times. To a certain extent this may be true; but when, as so commonly happens, there are clear signs of the former existence of a lake above the gorge, then the work must be considered essentially postglacial. For if the gorge had been cut under the ice, then no lake would accumulate in the valley above it when the ice melted away.

It is to be hoped that detailed observation may be directed to some good examples of these attractive elements of our scenery, and that clearly drawn topographical and geological maps may be prepared to illustrate the peculiarity of their forms. A set of large diagrams, in which views and maps of our gorges might form several members, is greatly needed to aid the teaching of geography by giving far clearer understanding of the typical forms of landscape than is possibly attained from description or from the small figures given in ordinary text-books. Cannot some of those who enjoy appreciative study of local geography during their summer tours aid in the collection of such material? The points of special importance for observation are: the topography and the general geological structure of the region; transverse profiles of the stream above, below and in the gorge; a longitudinal profile of the gorge showing its length, depth and descent; evidence to prove the existence of an obstructed channel between the open parts of the old valley above and below the gorge; effects of the obstruction in forming a lake, marsh or meadow above the gorge, and especially any terraces showing the former stand of a lake above the present level of discharge. Maps, sections and views would greatly improve a verbal description. The small advantage taken of the numerous opportunities for such work as this shows the little success of our geographic teaching.

Cambridge, Mass., June, 1884.

Art. XIX.—*The Influence of Light on the Electrical Resistances of Metals;* by Arthur E. Bostwick.

The fact that light has an influence on the electrical resistance of the element selenium has been known since 1832. The discovery was made by Superintendent Mai of the Valentia cable station, and the results of a few experiments on the subject were communicated to the Royal Society by Lieutenant Sale* in March of the year above mentioned. Since that time this property of selenium has received further investigation at the hands of Professor W. G. Adams, Dr. W. Siemens and others, and some recent applications of it, more or less practical in their nature, have made it familiar. In connection with the experiments on selenium it has also been established that tellurium possesses the same quality of having its resistance affected by light, though in a much less degree.

The effect of light on these substances is to diminish their resistance. In the case of selenium this diminution has in some instances been found to amount to a large proportion of the entire resistance.† Tellurium shows a diminution of less than one per cent, the greatest diminution obtained by Adams being one three-hundredth.‡

In the year 1877, Dr. Richard Börnstein of Heidelberg§ attempted to show that the property which had been established in the case of selenium and tellurium was not peculiar to those substances, but was possessed in common with them by gold, silver, platinum, and probably by all other metals, though in a very much less degree. He announced as the result of his experiments that the effect of light upon gold, silver and platinum was to diminish their resistance by from one and one-half hundredths of one per cent up to four per cent of the whole resistance. Shortly after this, Siemens‖ and Hansemann¶ of Berlin undertook and completed an investigation in which they were totally unable to detect any action like that described by Börnstein. The matter rested here until 1881, when Börnstein published** an account of a new series of experiments, from the results of which it would appear that the electrical resistance of silver is diminished one and one-fourth hundredths of one per cent by the action of light. As far as the writer knows, nothing more had been published on the subject when he made the

* Proc. Roy. Soc. Lond., May, 1873.
† C. E. Fritts "On a New Form of Selenium Cell;" this Journal, Dec., 1883.
‡ Proc. Roy. Soc. Lond., June 17, 1876 and Jan. 6, 1876.
§ Phil. Mag., V, vol. iii, 1877, p. 481.
‖ Berlin Monatsberichte, June, 1877. ¶ Ibid.
** Carl's Repertorium, xvii Bd., 2 und 3 heft, S. 164.

series of experiments which are to be described in the present paper.

Börnstein's first series of experiments were made upon platinum wires and thin leaves of gold, silver and platinum, mounted on glass. His principal methods were two in number. The first consisted in the comparison of the resistances of two wires or plates by means of a Wheatstone's bridge, the plates being alternately illuminated. The second method consisted in the observation of the logarithmic decrement of the swing of a galvanometer needle, the galvanometer being coupled in a circuit with a single plate which was alternately lighted and darkened. The latter method is the one known as Weber's method of damped vibrations. By these methods Börnstein obtained results, which, although alike qualitatively, differed a great deal in amount. Each set seemed to show that the resistance of the metals examined was diminished by light, but the diminution shown by the first method was only about one one-hundredth of one per cent, while that shown by the second was from three to four per cent. This difference Börnstein accounts for by supposing that the passage of an electric current through a metal diminishes its sensibility to light. The metals would then be more sensitive when traversed only by the extremely feeble currents induced by the swinging needle, than when the comparatively powerful current necessary in the Wheatstone's bridge was passing through them. Börnstein's results seemed to show also that the action of light on the metals experimented upon was greatest when they had been kept in darkness for some time, —a fact which had already been observed in the case of selenium.

The methods used by Siemens and Hansemann differed from both of those employed by Börnstein. These observers made no direct measurements but noted merely the slight changes of position of the index of a very sensitive galvanometer which was coupled either in a Wheatstone's bridge, or in a simple circuit with a source of electricity and the metal plate to be examined, the plate being illuminated and darkened at short intervals. In Hansemann's investigation, by means of a chronograph, an exact record of the oscillations of the index was kept and curves drawn to represent them. These curves give no evidence whatever that the movement of the index depended in any way on the illumination of the plates. The circuit was closed for from five to ten minutes at a time, the light being thrown on and off the plates every twenty seconds. The movement of the needle during any period of illumination or non-illumination never exceeded ten scale divisions, and its direction as often indicated an increase as a decrease of resistance. The sensitiveness of the galvanometer was tested at each series

of observations, and it was found that a scale division corresponded to a change in the resistance of about five-thousandths of one per cent. It will be noticed that the circuit was closed during the entire time of each set of observations. In view of Börnstein's theory that the passage of a current diminishes the sensitiveness of a metal to light, Hansemann used as source of electricity an iron-copper thermo-element having an electromotive force of less than ·001 volt, and producing a current comparable with those induced by the swinging needle in the damping method. Hansemann also tried a series of experiments by the damping method and found no diminution of resistance. The change, however, which he could have detected by this method was not much under one per cent.

Börnstein's second series of observations were entirely upon silver, deposited chemically on glass, and consisted of direct measurements of the ratio of the resistances of two plates by means of a Wheatstone's bridge, with sliding contact wire. He exposed his plates to the light for periods of fifteen minutes each. The mean of his results shows a diminution of one and one-quarter hundredths of one per cent, which he attributes to the action of light.

The experiments of Siemens and Hansemann seem to Börnstein to prove nothing concerning the influence in general of light upon the resistance of metals. For in them the plates were constantly traversed by a current, and moreover the illumination was for exceedingly short intervals. As regards the first condition, we know nothing of the influence of the electric current upon thin sheets of metal, and this influence should therefore be as much as possible done away with in searching for a delicate effect, and in the second place the light effect, if there is one, may take considerable time and the exposures should therefore be reasonably long. Börnstein therefore ascribes the fact that he obtains a different result from Siemens and Hansemann to his long exposures and to the fact that the current passed through his plates only during the short time occupied in making the measurements.

The further discussion of these points is left until after the description of the experiments made by the writer.

These experiments were made in the Yale College Laboratory in a room from which light could be entirely excluded. The walls and furniture were painted black. The plates of metal used were five in number and will be distinguished by the letters A, B, C, D and E. A and B were of silver deposited on plate glass by the method given in Browning's pamphlet "A Plea for Reflectors." They were thin enough to transmit about fifty per cent of light and were three and one-half inches long by two broad. These plates were mounted on a slab of

wood having two holes two and one-half inches square cut in it. Over these holes the plates were laid, the edges resting for three-eighths of an inch upon rolls of silver foil, through which the connections were made. Two strips of wood were screwed down over the edges of the plates to fasten them, and both sides of the slab were then covered with black paper, holes being cut in it slightly smaller than the plates. The plates, thus mounted, were held in a common clamp-stand. These plates were afterward shaved down to strips one-eighth of an inch wide. In this state they will be referred to as A′ and B′. C, D and E were plates of platinum, gold and silver respectively, deposited on glass in vacuo by Professor A. W. Wright some years ago. They were all thin enough to transmit light easily and measured one and one-half by one inches. These plates were mounted in a small black wooden box having a hole the size of the plate on either side, to admit the light. The plates rested on strips of platinum foil, through which the connections were made, and against which they were firmly pressed by hinged flaps of wood, which could be screwed down as tightly as desired.

The resistances of the plates and connections were as follows:

A	5·5	ohms.	Connections	·087	ohms.
B	12·	"	"	·083	"
A′	74·56	"	"	·087	"
B′	126·72	"	"	·083	"
C	9·33	"	"	·045	"
D	6·25	"	"	·045	"
E	10·27	"	"	·045	"

Galvanometer.—A Thomson's reflecting galvanometer of 7096 ohms resistance was used. Its two coils were connected in multiple arc, making the resistance 1774 ohms. The slit was adjusted so that the spot of light was about two millimeters in width, and the position of the right hand edge was read with the assistance of a small magnifying glass. The feeble light necessary for reading the scale was obtained, sometimes by reflecting the vertical rays of the galvanometer lamp from a sheet of white paper; sometimes by admitting a little light through a shutter. Generally, however, as it was necessary only to record the movement of the index over a few scale divisions, the light from the spot itself, owing to its size, enabled its position to be easily read off. The scale used was a straight one. A resistance box made by Elliot was employed by means of which 12320 ohms could be introduced into the circuit by pulling out plugs. It was arranged on the decimal system.

Rheostat.—A sliding rheostat was used, having two parallel platinum wires which could be connected in series or multiple

arc. Each wire was one meter in length and had a resistance of two ohms. The slide was worked by a long handle so that the observer was never near the rheostat wire except for the few seconds occupied in reading the scale. The latter was directly beneath the wires and was graduated to millimeters. At the end of the handle a micrometer screw was so arranged that the slide could be moved an exact number of millimeters. The rheostat was connected to the resistance box by a wire of ·289 ohm resistance, which was taken into account in making all measurements. The rheostat wire was protected from the direct radiations of the galvanometer lamp by a wooden screen and no trouble from this source was experienced.

Battery.—A single Daniell cell of from ten to sixteen ohms resistance was used. Very rarely two cells were used, coupled in series. A key which could be used as a commutator, or simply as a make and break circuit, was introduced in the battery circuit.

Source of Light.—This was a common argand gas burner, surrounded by a copper jacket having in its side a small circular opening. The rays from this opening were brought to a focus by means of a lens, at some little distance from the plate, so that the spot of light thrown upon the latter was about one and one-half inches in diameter. A screen, under the control of the observer, served to cut off the rays from the plate where it was desired. A cubical glass cell with a side of three and one-half inches and filled with a saturated solution of alum, was used in nearly all the experiments to cut off the obscure radiations of the lamp from the plate. In one series, sunlight was used, a beam from a heliostat placed in an adjoining room, being admitted through a hole in the wall. The spot of light on the plate was of the same dimensions as before.

On account of the increase of temperature in the room it was found necessary during part of the series of experiments to place the plates in a separate apartment, the light being admitted to them through a hole in the wall.

Methods.—It is impossible to say *à priori*, whether an effect of light on the electrical resistance of a metal, if there were any such effect, would be instantaneous or gradual. If the effect were an apparent one, due to some direct action of the radiation upon the current passing through the metal, the former would probably be the case, but if the light effected some change in the molecular structure of the metal, it would doubtless take place somewhat gradually. However this may be, it was thought best to divide the experiments into two classes; first, those to discover whether there were an instantaneous effect of light, and second, those to discover the effect of exposures for periods of from ten to fifteen minutes.

Method I.—The plate was connected as one arm of a Wheatstone's bridge. Two of the other arms were made up of resistance coils, and remained constant; the fourth could be varied by pulling out plugs from the resistance box and by means of the rheostat, whose wires were connected in series. The resistance of the plate was measured in the ordinary way to the tenth of an ohm by the resistance box, and further decimal places were obtained by the rheostat, care being taken to determine the length of double wire having a resistance of one ohm at each observation. This was found not to vary at any time more than a few millimeters from 265.

The resistance of the connections was determined at the close of the series by substituting for the plate a sheet of silvered copper of negligable resistance.

The sensibility, or number of scale divisions traversed by the index for the introduction into the circuit of one millimeter of rheostat wire, was also determined for each set of observations in the following manner. The micrometer screw at the end of the rheostat slide was so adjusted as to allow the slide a movement of just one millimeter. Ten readings of the index were then taken, the slide being alternately at its extreme positions. The mean of the differences between every two successive readings was taken as the deflection sought. By this method the effect of a steady movement of the index in one direction during the determination of the sensibility was eliminated. As the stream lines in the plate can be regarded as approximately parallel, the ratio of the resistance of the illuminated portion to that of the whole plate is sensibly that of their areas.

The percentage of change of resistance in the lighted portion of the plate corresponding to a movement of the galvanometer index one scale division evidently

$$= \frac{100}{r \,.\, s \,.\, n \,.\, \mathrm{R} \,.\, a},$$

where "r" is the ratio of the constant arms of the bridge, "s" the sensibility for one millimeter, "n" the length of rheostat wire having a resistance of one ohm, "R" the resistance of the plate, and "a" the fraction of the plate covered by the light spot. It is assumed that the observer could detect a movement of the index amounting to one-fourth of a scale division.

The method, then, was as follows: The plate resistance and sensibility having been determined, the index was balanced and the circuit closed. When the spot was perfectly still, the light was suddenly thrown on the plate and the movement of the index, if any, was noted. The spot had generally a steady

movement toward the left corresponding to the increased resistance of the plate caused by the heating effect of the current, and to avoid waiting for the moments when it was at rest the following method was also used. The movement of the spot for three periods of ten seconds each was recorded, the plate being lighted during the middle period, and the difference between the second reading and the mean of the first and third was taken as the effect produced by the light. Plates A and B were illuminated both with gas and sunlight,—C, D and E with gas light only.

The illumination with sunlight took place directly after the series of observations described under method II, and the connections were therefore left as in that method. The formula used for calculating the percentage of change of resistance corresponding to a galvanometer deflection of one scale division will also be found there.

Method II.—Plates A and B were connected as two arms of the bridge. The other two arms each consisted of part of the resistance box and part of the rheostat, the wires of the latter being connected in multiple arc. Moving the slide therefore increased the resistance in one arm and diminished that of the other. The length of wire having a resistance of one ohm was thus determined. The index was balanced, one ohm taken from the box and the index again balanced. Calling the amount by which the rheostat slide was pushed up M, and the length of wire having a resistance of one ohm n, 10 and 25 ohms respectively being the resistances in the box,

$$25 : 10 :: 24 + \frac{M}{n} : 10 - \frac{M}{n} \text{ approximately.}$$

From this n was found in terms of M, and was found equal to 1100^{mm}. As the plates were lighted alternately, it was assumed that the effect of the light on the one died away at the same rate that it increased on the other. The percentage of decrease of resistance of one plate would then equal the percentage of increase in the other and the observed effect would be due to the sum of these two. The percentage of change in both plates which would produce a movement of the index equal to that caused by moving the slide one millimeter was calculated thus. If x is this percentage, then for plates A and B when the ratio of the resistances in the box was 25 : 10—

$$25 + \frac{1}{1100} : 10 - \frac{1}{1100} :: 25 + \frac{25x}{100} : 10 - \frac{10x}{100} \quad \therefore x = \cdot 006 \text{ per cent.}$$

For A′ and B′ when the ratio of the resistances in the box was

$$186 : 110 \qquad x = \cdot 001 \text{ per cent.}$$

When plates A and B were illuminated by sunlight as mentioned above, they were connected as in this method. The change of resistance corresponding to a given deflection was therefore calculated as above, except that as the light was not shifted from one plate to the other, the effect must be considered as produced by a change in the resistance of one plate instead of being the sum of equal changes in two plates, x was thus found in this case to equal ·013 per cent. The per cent of change corresponding to any deflection D was of course $\frac{Dx}{S}$, S being the sensibility.

The light was shifted from one plate to the other by moving the lens every fifteen minutes. During the last five minutes of each exposure, observations of the first elongation of the index were made once a minute and the means taken. Care was taken to read the zero point before taking each elongation. The circuit was closed for a few seconds only of the fifteen minutes of exposure. Plates A B, A′ and B′ were thus treated. With plates C, D and E the method of observation was the same, but the bridge was arranged as at first, only one plate being connected at a time, and this plate was alternately lighted and darkened at intervals of fifteen minutes. The change in the resistance of the plate corresponding to a deflection of one scale division was calculated as in method I.

It should be noted that the method of Hansemann, before described, was also tried but was not successful for the reason that on account of the long exposures it was necessary to keep the circuit closed for several hours at a time, instead of for a few minutes only, as with Hansemann, and during this time the variation of the index from change in the zero point and accidental causes was considerable. In this method there was observed a steady increase of the plate resistance caused probably by the heating effect of the current, or it may be by the passage of the current itself as claimed by Börnstein.

Tables of Results (method I).

Deflection to right corresponds to diminished resistance; to left—to increased resistance.

Date.	Plate	No. of obs.	Deflec. to right.	To left.	Zero deflec.	Max. deflec.	R. a	r.	s.	n.	Per cent change for ¼ sc. div.	So'ce of light.	Remarks.
1883. Feb. 13	B	12	--	--	12	--	$\frac{12}{3}$	100:10	1·8	266	·001	gas	No
14	B	12	--	--	12	--	$\frac{12}{3}$	100:10	4·3	265	·0006	gas	alum cell
15	B	12	--	--	12	--	$\frac{12}{3}$	100:10	1·9	274	·001	gas	used
19	B	12	--	--	12	--	$\frac{12}{3}$	100:10	1·3	268	·002	gas	
20	B	10	--	10	--	−1·5	$\frac{12}{3}$	100:10	1·8	271	·001	gas	
20	A	12	2	6	4	±1	$\frac{5·5}{3}$	100:10	3·5	264	·001	gas	
22	A	20	2	10	8	−1	$\frac{5.5}{3}$	10:10	14·0	264	·004	gas	
22	A	11	1	3	7	--	$\frac{5.5}{3}$	10:10	16·0	264	·003	gas	

Date.	Plate	No. deflections.	Mean deflections.	Max. deflections.	Per cent change for 1mm. Rh. wire.	r.	s.	n.	Per cent change corresp. to mean deflec'n.	So'ce of light.	Remarks.
Apr. 9	B	10	4·1	6	·013	25:10	10	1100	·005	sun	no alum.
9	B	10	2·	3	·013	25:10	10	1100	·003	sun	alum.
9	B	10	2·1	3	·013	25:10	10	1100	·003	sun	no alum.
9	B	5	2·	2	·013	25:10	10	1100	·003	sun	alum.
9	A	3	5·	6	·013	25:10	10	1100	·0065	sun	alum.

Date.	Plate.	No. obs.	Deflec. to right.	To left.	Zero deflections.	Mean movement for 10 sec. no light.	Ditto Plate lighted.	Diff.	R. a.	r.	s.	n.	Per cent change corres. to diff.
Apr. 16	C	22	1	12	9	−0·7	−·86	−·16	9·3 × 1	100:10	3·7	265	inc. ·0002
19	D	19	4	9	6	−0·3	−·48	−·18	6·3 × 1	100:10	4·3	265	inc. ·0003
25	E	12	7	5	0	+·12	+·4	+·28	10·3 × 1	100:10	6·6	265	dim. ·0002
25	E	8	2	5	1	Movement for 5 seconds +·65	(5 sec.) +·13	−·52	10·3 × 1	100:10	6·6	265	inc. ·0003

Results.—Method II.

Date.	Sensibility.	Plate lighted.	Elongation. Mean of 5.	Diffs.	Per cent Inc. in resist. of Plate lighted.	Per cent Dim. in resist. of Plate lighted.
Mar. 20	5·4	A	− 2·7	----	----	
		B	− 2·7	0	0	
		A	− ·8	+ 1·9	----	·002
		B	− 1·1	− ·3	----	·0003
		A	+ ·75	+ 1·8	----	·002
		B	+ ·2	− ·5	----	·0005
		A	+ 1·9	+ 1·7	----	·002
		B	+ 2·4	+ 0·5	·0005	
Mar. 29	1·3	--	+ 1·1	----	----	
		B	+ 2·	+ 0·9	·004	
		A	+ 1·9	− 0·1	·0005	
		B	+ 2·1	+ 0·2	·001	
		A	+ 1·7	− 0·4	·002	
		B	− 0·9	− 2·6	----	·012
		A	− 4·2	− 3·3	·017	
		B	−11·1	− 6·9	----	·037
Apr. 2	10·2	--	− 1·1	----	----	
		A	− 1·5	− 0·4	·0002	
		B	− 3·9	− 2·4	----	·0015
		A	− 4·7	− 0·8	·0005	
		B	− 4·4	+ 0·3	·0002	
		A	− 4·2	+ 0·2	----	·0001
		B	−15·4	−10·8	----	·0065
		A	−24·	− 8·6	·005	
Apr. 10	1·7	--	− 3·3	----	----	
		B′	+ 9·8	+13·1	·008	
		A′	+ 9·1	− 0·7	·0004	
		B′	+ 0·6	− 8·5	----	·005
Apr. 11	2·2	B′	+11·2	----	----	
		A′	+16·5	+ 5·3	----	·002
		B′	+51·8	+35·3	·016	
		A′	+42·	− 9·8	·004	
Apr. 12	2·5	--	− 0·7	----	----	
		B′	+ 6·9	+ 7·6	·003	
		A′	+ 0·8	− 6·1	·0024	
		B′	+17·	+16·2	·016	
		A′	+13·2	− 3·8	·004	
		B′	+20·6	+ 7·4	·007	
		A′	+16·9	− 3·7	·004	
		B′	+ 29·	+12·1	·012	

Results.—Method II—continued.

Date.	Remarks.	Plate.	Elongation. Mean of 5.	Diffs.	Per cent Inc. in resist. of Plate.	Per cent Dim. in resist. of Plate.
Apr. 17	s=2·2	C				
	r=100 : 10	(Platinum)				
	n=265	light off	− 9·2			
	R=9·3	on	−10·9	− 1·7	·003	
	a=1	off	−16·1	− 5·2	·009	
	1 sc. div.	on	−19·	− 2·9	·005	
	=·0018%	off	−19·1	− ·1	·0002	
	of plate					
Apr. 19	s=6·3	D				
	r=100 : 10	(gold)				
	n=265	light off	− 12·2			
	R=6·3	on	− 4·1	+ 8·1		·008
	a=1	off	+ 1·9	+ 6·		·006
	. .	on	+ ·5	− 1·4	·0014	
	1 sc. div.	off	+22·3	+21·8		·022
	=·001%					
	plate					
Apr. 26	r=100 : 10	E				
	n=265	(silver)				
	a=1	off	− 2·5			
	R=10·3	on	−18·	−15·5	·008	
	s=8	off	−36·	−18·	·009	
	1 sc. div.	on	−43·	− 7·	·004	
	=·0005%	off	−47·	− 4·	·002	
	of plate					
Apr. 27	R=10·3	off	− 2·8			
	s=2·5	on	−16·5	−13·7	·022	
	1 sc. div.	off	−34·4	−17·9	·029	
	=·0016%					
Apr. 28	s=6	off	− 6·6			
	1 sc. div.	on	+ 2·4	+ 9·		·006
	=·0007%	off	+70·	+67·6	irregularity in needle.	
		off	− 1·5			
		on	+ 3·6	+ 5·1		·003
		off	+ 7·5	+ 3·9		·0024

Summary of Results.

Instantaneous effect—(method I).

Plate A	Increase of a few thousandths of 1 per cent.	
B	No diminution of more than ·001 per cent.	
B	(Sunlight) increase of ·004 per cent.	
C	Increase of ·0002	per cent.
D	" ·0003	"
E	" ·00005	"

Long exposures—(method II).

A and B Mean effect on plate lighted—decrease of ·0014 per cent.
A′ and B′ " " increase of ·0053 "

	Mean effect of lighting plate.		Of darkening.	
C	increase	·004 per cent	increase	·0046 per cent.
D	diminution	·003 "	diminution	·014 "
E	increase	·005 "	increase	·007 "

It will be seen that the above results agree with those of Siemens and Hansemann rather than those of Börnstein. The latter's objections to Siemens and Hansemann's methods have already been mentioned. The first, that the experiments were made on the plate when the circuit though it was closed, apply of course also to method I of the series just described. In Börnstein's experiments by the damping method however, his plates were traversed by a current, though of course a very feeble one, and it is difficult to see how the difference between a diminution of five per cent and no perceptible effect can be accounted for by the fact that the current in one case was intermittent and in the other constant.

Börnstein's second objection relating to the length of the exposure is worthy of more attention. The exposures of Siemens and Hansemann and those of method I, above, were for a few seconds only. It seems well established then that the effect of light on the electrical resistance of metals is not instantaneous, and this is admitted by Börnstein. But method II to which neither of Börnstein's objections apply,—since the plates were exposed for periods of quarter of an hour each, and the circuit closed for only a few seconds of this time—also shows no appreciable diminution and it is this which conflicts most directly with Börnstein's conclusions.

In the experiments described above the connections of plates A, B, A′ and B′ were made with special view to the prevention of any thermo-electric currents which might be generated at the junction of two different metals by unequal heating and which might by their effect on the galvanometer simulate a decrease of resistance. It may be here remarked, however, that in searching for an effect of any kind, many precautions which become necessary as soon as the effect seems to appear, in order to try whether it be real or simulated, need not be taken when no effect at all appears. Thus it was thought unnecessary to make all connections by means of mercury cups, and common binding screws were used.

It may also be here mentioned that the effect whose existence is to be proved or disproved is of course the difference between the effects of the light and the heat of the luminous

rays. This is the quantity also measured in Siemens and Hansemann's experiments. Börnstein on the other hand, who used no alum cell, measured the excess of light effect over the heat effect of both luminous and obscure radiations, so that if there is a true diminution of resistance caused by light, it ought to have appeared more strongly in the experiments which have been described.

Taking all these things into consideration, it appears safe to say then that if light causes any diminution in the electrical resistance of metals, it probably does not exceed a few thousandths of one per cent.

Art. XIX.—*Vanadinite in Pinal County, Arizona;* by Francis Hayes Blake.

The rare mineral Vanadinite is found in the "Black Prince Mine," Pioneer Mining District, Pinal County, Arizona, in brilliant red and yellow hexagonal crystals. Qualitative tests show the presence of vanadium, chlorine and lead.

The crystals occur in the seams of a partly decomposed rock resembling trap, covering completely in some cases five square inches of surface. They vary in size from one sixty-fourth to one-eighth of an inch in diameter, sometimes reaching the length of one-quarter of an inch. They are often implanted by the side and are then doubly terminated. The majority of these crystals are of a deep red color; some vary from a red at one end through deepening shades of delicate straw-yellow to orange and red at the other end. Others exhibit a succession of layers of deep red and light yellow parallel to the basal plane. Many of the crystals are cavernous, and fibrous, resembling in their cavernous structure the prisms of pyromorphite. The prismatic planes I are striated vertically, which in this respect is just the opposite to what occurs in pyromorphite.

The simple hexagonal prism, without modifications, predominates as the crystalline form; although in some groups of crystals is found the combination of the two prisms I and i-2, with the basal edges replaced by planes of the pyramid of the first series. These planes are very minute. I was unable to find planes between O and i-2.

Wulfenite is also found in this mine but not in very perfect crystals.

Pinal, Pinal County, Arizona, June, 1884.

SCIENTIFIC INTELLIGENCE.

I. Physics and Chemistry.

1. *On the General Law of Solidification of Solvents.*—Raoult has studied the effect which is produced upon the point of solidification of a solvent by dissolving solid, liquid or gaseous substances in it. If A represent the coefficient of depression, that is the amount by which the temperature of solidification is lowered when one gram of the substance is dissolved in 100 grams of the solvent; M the molecular weight of the anhydrous substances and T the molecular depression of the freezing point (that is, the depression corresponding to the solution of one molecule of the dissolved substance in 100 grams of the solvent) then $MA = T$. The solutions employed were very dilute, containing less than one molecule (in grams) of the solid to two kilograms of the solvent. The solvents used were water, benzene, nitrobenzene, ethylene dibromide, formic acid and acetic acid, whose freezing points were respectively 0°, 4·96°, 5·28°, 7·92°, 8·52° and 16·75°. The following are the conclusions reached: 1st, All bodies, whether solid, liquid or gaseous, when dissolved in a definite compound liquid, capable of solidifying, lower the point of congelation. 2d, There is for each solvent a maximum molecular depression of the freezing point. And 3d, With all solvents, the molecular depression of the freezing point, due to the different substances dissolved, approximates to two mean values, differing with the character of the solvent, one of which is double the other. Thus for ethylene dibromide these values are 117 and 58, for nitrobenzene 72 and 36, for benzene 49 and 24, for acetic acid 39 and 19, for formic acid 28 and 14 and for water 37 and 18·5. The greater of these two values, which the author calls the normal depression, is much the more frequent, except in the case of water. Since, with the same solvent, the substances producing either the normal or abnormal depression belong to well-defined groups, the depression observed may be made use of in fixing the molecular weight. All salts of the alkalies for example, when dissolved in water, produce a molecular depression of about 37; hence among many multiple values of the molecular weight of such a salt, that one is selected which multiplied by the coefficient of depression of the salt in water, gives a product nearest to 37. For organic substances soluble in water, that value is chosen which when multiplied by the coefficient of depression gives a value nearest to 18·5. The foregoing facts seem to the author to justify the following generalization: For a constant weight of a given solvent, all physical molecules of whatever nature, produce the same depression of the freezing point. When the bodies dissolved are completely disaggregated, as for example, when they are in the state of vapor, so that each physical molecule contains only a single chemical molecule, the

molecular depression is a maximum and the same for all bodies. When the chemical molecules are united in pairs to form the physical molecule, the depression has only one half its former value, since the double molecule produces no more effect than the single one. If the maximum molecular depression be divided by the molecular weight of the solvent, the quotient expresses the depression produced when one molecule of the substance is dissolved in 100 molecules of the solvent. This value is for formic acid 0·63, for acetic acid 0·65, for benzene 0·64, for nitrobenzene 0·59, and for ethylene dibromide 0·63; being practically the same for all. For water however, the value is 2·61, a value four times too large. This the author explains by the hypothesis that the physical molecule of water consists of four chemical molecules. The general law of solidification of solvents, Raoult enunciates finally as follows: If one molecule of any substance be dissolved in 100 molecules of any liquid, of a different nature, there is produced a depression in the freezing point of the liquid which is always about the same and approaches very near the value 0·63. Consequently, the depression of the freezing point of a dilute solution, of whatever sort, is sensibly equal to the product which is obtained by multiplying the number 63 by the ratio between the number of molecules dissolved and the number of the dissolving molecules.

In subsequent papers, Raoult considers the application of this law to the study of the distribution of acids and bases in solution, and of the freezing point of acid and alkaline solutions. With reference to the latter, he concludes as follows: Acids and bases in this respect, may be sharply divided into two groups. The first comprises those which produce a normal molecular depression of the freezing point near 40°. The second includes those acids and bases which produce an abnormal molecular depression near 20°. The bases of the first group are all analogous to potassium hydrate and, like it, are capable of displacing from their chlorides all the bases of the second group. The acids of the first group are all strong acids like hydrochloric acid, and like it, are capable of displacing from their alkali-salts all the acids of the second group.—*Ann. Chim. Phys.*, VI, ii, 66, 93, 99, 115, May, 1884.

G. F. B.

2. *On the Production of Cyanides and Ferrocyanides from Trimethylamine.*—On calcining the residue from the distillation of alcohol made by the fermentation of beet-root molasses, there is produced, as Vincent has shown, a large quantity of trimethylamine; one establishment at Courrières producing 1800 kilograms of trimethylamine salts per day from this source. Some time ago Ortlieb and Müller modified the Solvay process so as to adapt it to the preparation of potassium bicarbonate from the chloride, by using trimethylamine in place of ammonia; carbon dioxide gas being passed through a saturated aqueous solution of one molecule of normal trimethylamine carbonate and two of potassium chloride at 23°, until potassium bicarbonate, representing nearly 40 per cent of the chloride, was precipitated. These

same chemists have now introduced into the chemical works at Croix a process for the manufacture of cyanides from trimethylamine. On passing this substance through a red hot porcelain tube, it is decomposed and yields hydrogen cyanide, ammonium cyanide and hydrocarbon gases. On the large scale, retorts are used like those employed in the manufacture of gas, and the products are passed, first through dilute sulphuric acid to retain the ammonia and then through caustic alkali to absorb the hydrogen cyanide. The gases are collected in a gasholder and used for illumination. To prepare the ferrocyanides, a known quantity of ferrous oxide is dissolved in the alkali-cyanide solution, obtained as above.—*Bull. Soc. Ch.*, II, xli, 449, May, 1884.

G. F. B.

3. *On the Preparation of Marsh Gas.*—Some years ago, GLADSTONE and TRIBE pointed out that by the reaction of the copper-zinc couple upon methyl iodide in presence of water or alcohol, marsh gas was readily produced, as follows:

$$CH_3I + H_2O + ZnCu = CH_4 + ZnI(OH) + Cu.$$

These chemists have now devised a process by which this reaction may be used for the preparation of marsh gas without the large loss at first experienced. 550 grams of somewhat thinly granulated zinc were placed in a 600 c.c. flask, and 150 grams in a glass tube one inch in diameter and twelve inches long. This tube was fixed above the flask like an inverted condenser. After cleaning the zinc with dilute sulphuric acid, it was treated three times with a solution of copper sulphate until all the copper had been precipitated on the zinc, and then well washed, first with water and then with alcohol. The apparatus was then put together and by means of a tap funnel opening into the flask 20 c. c. of methyl iodide and the same volume of alcohol were allowed to run into the latter upon the copper-zinc couple. The reaction began at once, the first liter of marsh gas being collected in eight minutes. As a result 7500 c. c. of the gas was obtained, or 7053 c. c. reduced to normal temperature and pressure. As the theoretical yield is only 7100 c. c. the process gives about 99·3 per cent of the total quantity obtainable. The operation can be shortened by raising the temperature. Vapors of methyl iodide and alcohol accompany the gas.—*J. Chem. Soc.*, xlv, 154, May, 1884.

G. F. B.

4. *On the Crystalline Form of Beryllium.*—BRÖGGER and FINK have examined the crystalline form of metallic beryllium. The crystals were exceedingly minute, the faces having a breadth of only 0·005 to 0·001 millimeter. They were very brilliant and of a steel-gray color. On examination they proved to be holohedral forms belonging to the hexagonal system, the ratio of the axes being 1 : 1·5802 as calculated from the angle between the basal plane 0P and the pyramid P, which was 118° 43½′. The faces observed on specimens furnished by Nilson and Pettersson were: ∞P, ∞P2, 0P, P; and in addition, on the specimens from

Pettersson and Humpidge, the pyramid $\frac{1}{2}$P. The authors think the analogy close between beryllium and zinc, the latter being in all probability holohedral.—*Ber. Berl. Chem. Ges.*, xvii, 849, April, 1884. G. F. B.

5. *On the Vapor-density of Beryllium Chloride.* — The importance of the atomic weight of beryllium in connection with the periodic law, has led NILSON and PETTERSSON to undertake the determination of the vapor density of its chloride. This compound was prepared by heating the metal in a current of dry hydrogen chloride gas. But as its vapor corrodes glass the operation had to be conducted in a narrow tube of platinum. The chloride is an easily fusible and volatile snow-white mass, made up of minute crystals sometimes transparent. To determine the vapor density a platinum tube was enclosed in a tube of difficultly fusible glass and placed in an iron tube in an ordinary combustion furnace side by side with another similar tube containing an air thermometer. The expelled gases were measured on separate manometers. Since the chloride loses chlorine in presence of air, the tube and manometer were filled with carefully dried carbon dioxide before it was introduced. The vapor densities were, at 490°, 6·7; at 520°, 4·174; at 589°, 3·067; at 597°, 3·031; at 604°, 3·090; at 686°, 2·853; at 720°, 2·926; at 745°, 2·753; at 812°, 2·793. The calculated vapor density is for Be''' 13·65 and Be_2Cl_6 8·310, $BeCl_3$ 4·155. For Be'' 9·10 and $BeCl_2$ 2·770; and for Be' and BeCl, 1·385. Hence in the state of a perfect gas, from 686° to 800°, the molecule of beryllium chloride is represented by the formula $BeCl_2$ and the atomic weight of beryllium must be considered as 9·10.—*Ber. Berl. Chem. Ges.*, xvii, 987, May, 1884. G. F. B.

6. *On Anthemene, a hydrocarbon from Chamomile.*—In examining the residue from the evaporation of the solvents used in the extraction of the flowers of chamomile (*Anthemis nobilis*), NAUDIN discovered two white crystalline solids, separable from each other by treatment with cold absolute alcohol. The one least soluble fused at 63°–64°; the other at 188°–189°. From a kilogram of the flowers, 1·5 grams of the former and 4·5 grams of the latter were obtained. The former body only has been examined. It crystallizes in fine microscopic needles without odor or taste, boils at 440° and has a specific gravity of 0·942. It is insoluble in water but soluble in ether, ligroin, carbon disulphide, chloroform, etc. On elementary analysis it afforded, as a mean of many accordant analyses, carbon 83·80, hydrogen 14·40 = 98·20; a loss of 1·80 per cent. Repeated by Schützenberger, the analyses still showed a loss of 1·53 per cent. The formula $C_{18}H_{36}$ requires 85·82 carbon and 14·18 hydrogen. Its vapor density was found to be 127. The author is inclined to consider it as an octodecene with a closed chain; and proposes to call it β-octodecene or anthemene.—*Bull. Soc. Ch.*, II, xli, 483, May, 1884. G. F. B.

7. *On Lactosin, a new Carbohydrate.*—MEYER has described a new carbohydrate closely resembling dextrin and which seems

to play the same part in the caryophyllaceæ that inulin does in the compositæ. It was obtained from the roots of *Melandryum album* G. and of *Silene vulgaris* G. by precipitating the juice first with a small quantity of alcohol to separate the proteids and then with a larger quantity to precipitate the new body. After preliminary purification, it rotated to the right $(\alpha)_D = +168°$ and finally $+190°$. After boiling with 80 per cent alcohol, it crystallized in small brilliant crystals. On inversion it gives lactose and a new difficultly crystallizable sugar. The formula $C_{36}H_{62}O_{31}$ is assigned to it and the name lactosin.—*Ber. Berl. Chem. Ges.*, xvii, 685, April, 1884. G. F. B.

8. *A method of determining the Standard of Light adopted by the Paris Conference.*—The International Conference lately held at Paris adopted as a standard of light the amount emitted by one square centimeter of melting platinum at the point of solidification. WERNER SIEMENS points out that the practical determination of this unit is beset with difficulties, since platinum at the melting point readily takes up foreign substances which change this melting point. He therefore recommends the use of the following apparatus, which, however, determines the light given out by the platinum at the point of melting and not at the point of solidification. With pure platinum, however, the difference is very small. The method is based upon the melting of a very thin plate of platinum by a current of electricity. The platinum is enclosed in a metallic case provided with a hole 0·1 square centimeter in section, which is immediately over the melted platinum. The sides of this hole are conical and the platinum foil extends beyond the hole in every direction. At the instant of the melting of the foil a quantity of light equal to 0·1 of the standard is emitted from the hole. By suitable modification of the strength of the electrical current the melting of the platinum can be delayed until the proper moment of comparison with another light has arrived. Preliminary measurements with this apparatus show that the light emitted from the hole at the point of melting of the platinum is about 1·5 times the English standard candle.—*Ann. der Physik und Chemie*, 1884, No. 6, p. 304. J. T.

9. *The boiling point of Oxygen, of Air, and of Carbonic oxide under atmospheric pressure.*—M. S. WROBLEWSKI has shown that a fall of temperature of $-186°$ C. can be obtained by the expansion of liquid oxygen. In continuing his work he discovered that a hydrogen thermometer of small size could not be depended upon, and therefore adopted a thermo-electric apparatus, using an aperiodic galvanometer of large resistance and great sensibility. The inductions of this electrical apparatus were afterwards compared with a large hydrogen thermometer. By this method working at the low temperature of $-200°$ C. the $\frac{1}{1000000}$ of a volt could be measured. This corresponds to a change of $\frac{1}{5}$ of a degree of temperature. With this apparatus the author has been enabled to measure the boiling point of oxygen, of air, of nitrogen and of carbonic oxide under the ordinary pressure.

These gases are obtained as liquids by leading them from a metallic receiver, where they are already compressed to 100 atmospheres, into a glass tube closed at one end and immersed in liquid oxygen. On the expansion of the oxygen, the compressed gas is liquefied. When the expansion is accomplished the connection of the tube with the receiver is broken, and it is brought slowly to the atmospheric pressure; the liquid gas boils at a temperature corresponding to this pressure. M. Wroblewski obtains the following results:

Oxygen, boiling point	−184° C.
Air, " "	−192·2°
Nitrogen, " "	−193·1°
Carbonic oxide,	−193°

On evaporating these gases *in vacuo* a temperature of −200° C. can be obtained. It results from the above that ordinary air promises to be the refrigerator of the future. It does not require to be prepared; to use it, it should first be compressed to the point of liquefaction in metallic receivers. It should then be allowed to pass into the receivers already cooled when it will be liquefied, and it can then be allowed to flow out. This use of air involves no technical difficulties, and success depends only upon the material means at the disposal of the experimenter.—*Comptes Rendus*, April 21, 1884. J. T.

10. *The Scientific Papers of James Prescott Joule, D.C.L., L.L.D.*, etc. 657 pp. 8vo. London: 1884. (Taylor & Francis.)—The Physical Society of London has done a most important work for the advancement of physical science in collecting and reprinting the papers of Dr. Joule, and thus putting them in convenient form for the use of students and workers. The importance and lasting value of Dr. Joule's contributions to Physics are so well known that this collection must be at once received with the appreciation which it deserves. The papers included are arranged in order of publication and number about one hundred, some of which, however, are very brief. The most important of the memoirs are those devoted to the discussion of the experiments by which the mechanical equivalent of heat was determined, a subject with which the name of Dr. Joule will always be connected; in first proving the existence of this relation and then determining its value, and that with a marvelous degree of accuracy, Dr. Joule made a contribution to the advance of physical science which is second to no other in the history of the science. A considerable number of the papers in the volumes are more or less closely related to this subject. Some of the other more important memoirs are on specific heat; on the effect of magnetism on the dimensions of iron and steel bars; on the thermo-dynamic properties of solids; on the surface condensation of steam. This volume is soon to be followed by a second containing papers published by Dr. Joule in conjunction with other men of science.

11. *Whirlwinds, Cyclones and Tornadoes;* by WILLIAM M. DAVIS. 90 pp. 16mo. Boston: 1880. (Lee & Shepard.)—The author has presented in this little volume (reprinted from Science)

a brief but clear and readable statement of the theory of storms. The subject is one which now compels serious attention in certain parts of the country, and this concise exposition is consequently very opportune.

II. Geology and Natural History.

1. *The Kame Rivers of Maine;* by George H. Stone, of Colorado Springs, Colorado. (Abstract from the Proc. Amer. Assoc., 1883.)—Nearly all glacialists now agree that most of the kame gravels of the drift region were deposited by glacial streams. There remains a difference of opinion as to whether these streams were sub- or super-glacial; but for the sake of brevity no reference is here made to the literature of the subject. In my studies of the drift in Maine, I think I have found evidence of both kinds of streams.

During an exploration of Maine which continued for about five years, I had opportunity to examine many thousands of sections of the till throughout the greater part of the state. I have never found stratified or even water-classified material enclosed in this formation, except within a few miles of the coast, or so near to the surface as to leave the interpretation in doubt. Hundreds of miles of the beds of the inland streams have been examined by me, and if water-washed material exists in the till in the interior of the state, it must be rare. But near the coast, as for instance at Portland, one may see small masses of sand nearly or quite surrounded by the unmodified till, the clayey till being in such contrast with the clean, siliceous sand, that the difference in composition and mode of formation is seen at once unmistakably. These masses of sand and gravel in the till are often not now stratified, but all have been plainly classified by running water and not afterward so mixed with the clayey till as to lose their identity, If a ribbon or pocket of sand, not an inch in thickness, can be thus plainly distinguished from the amorphous till, surely the absence of such deposits from the great interior region is strong indication that the conditions were there different from what they were near the coast. A somewhat positive indication of what this difference was is found in the existence of pot-holes near the coast in situations where no ordinary surface streams can ever have flowed. These pot-holes must be regarded as the work of glacial streams. In the interior no pot-holes have been found except in the valleys of ordinary streams.

Before interpreting these facts, let us consider the causes of the melting of a glacier. The white color and porous structure of the surface ice of a glacier show where most of the melting takes place. This superficial water flows along the surface, or it may wear and melt a deeper and deeper channel until it disappears down some crevasse and becomes a sub-glacial stream. Modern glaciers show a difference in their glacial streams. Near the lower extremity almost all the water is sub-glacial. The ice is so broken

by crevasses that the melting waters almost immediately plunge to the bottom. But as we go backward toward the line of perpetual snow, where the ice is thicker and the melting less rapid, we find streams upon the surface, the length depending upon the extent of ice free from crevasses. How far do these conditions represent those of the great glacier of eastern North America?

Without some limitation, it is doubtful if the analogies of any modern glaciers, even of Greenland glaciers, can be admitted as valid in the case of the great ice-sheet. The Greenland glaciers do not wholly overlap large areas like the great ice-sheet, but here and there peaks emerge from them which form crevasses and assist the waters to pass beneath the glacier. However, waiving these objections, and admitting for the time that the sub-glacial streams of our great glacier were as well developed as those of the Greenland glaciers of to-day, at the same time we must admit that the surface streams were as well developed. Now the superficial streams of the Greenland glaciers are often of considerable size; therefore we must believe that large surface streams existed upon the ice-sheet at a proper distance north from its terminus. It should be noted that this is the condition of the Greenland glaciers during a time of comparative stability, or, quite probably, of their slow increase in extent and depth.

But what would happen during the final melting of the ice-sheet? All substantially admit that this melting was very rapid and that it took place upon a great width simultaneously, although the ice, being thicker toward the north and in a colder mean climate, would not become melted so quickly as farther south. As I have elsewhere pointed out, no southward motion would be possible over a large part of Maine, after the thickness of the ice was reduced to about five hundred feet, on account of transverse ranges of hills. Nowhere except in the White Mountains have I found traces of glaciers following local valleys. Apparently, almost all flow ceased after the melting had so far proceeded that the hills appeared above the ice. Under these conditions no new lines of crevasses would open in the thinning ice-fields, even after the hills began to emerge. The melting took place so rapidly, and the motion of the ice ceased so completely that there would be no time for the formation of sub-glacial channels. On the contrary, the exigency of glacial melting, supplemented by the summer precipitation, would cause a great extension of the superficial streams.

The presence of glacial pot-holes in Maine near the coast, and the masses of water-washed matter in the till, show that the glacial streams there reached the ground. The most of the area of sub-glacial streams must have lain south of the present coast-line. The glacier reached out into the Gulf of Maine, and off its front were probably numerous boiling springs of fresh water, like those at the submerged extremities of the Greenland glaciers. The ice over the great interior region of the state was for the most part drained by superficial streams. When the melting had so far proceeded that the bottoms of these streams reached the moraine stuff,

which was scattered through the lower part of the ice, then the kame-gravel began to gather on the bottoms of their channels. Several of these kame-rivers were a hundred or more miles long, as is shown by my map of the kames of Maine, published in the Proceedings of the Association for 1880. Most of the kame-rivers have been described by me as probably flowing in channels formed superficially on the ice, and that is my opinion still. Near the coast these channels may originally have been of sub-glacial origin. Northward there was a region where the drainage of the glacier was chiefly by surface channels which finally found their way beneath the ice at the southern limit of this region. The final melting of the great glacier took place largely at the surface, and this melting, together with the large rainfall, caused great bodies of water to collect on the ice, finally wearing and melting deep channels. In some cases these streams probably followed previously formed sub-glacial channels for a part of their course, widening them until the ice-arch collapsed by its own weight.

We may grant as great a development of sub-glacial streams in the ice-sheet as anyone can reasonably consider is demanded by the Greenland glaciers, and yet I cannot see how this furnishes any adequate representation of the conditions during the final melting, when there was so vast an accession of surface water, and also when the ice-flow had so far ceased as to make it certain that few if any additional crevasses would be formed. Under these circumstances there could be no time to extend the previously formed sub-glacial channels far, and the sudden floods would find their way over the lowest parts of the ice just as they would over the ground. A great and sudden northward extension of the superficial streams would be the result.

The above reasoning applies to Maine only, and other regions are to be studied by themselves. Part of the reasoning will probably apply to most or all of the glaciated area of North America, but with many differences in details. Indeed, as glacialists come to better appreciate the great variety of work which the ice-sheet performed, the less likely will they be to contend for the privilege of imposing the local conditions, with which we are most familiar, upon the whole drift-covered area.

2. *Notes on Tertiary Shells;* by Otto Meyer (Proc. Nat. Sci. Philad., 1884, p. 104).—Mr. Meyer, who is well versed in the Tertiary paleontology of Europe through his studies and investigations, gives the results in this paper of his examination of certain American species. He identifies *Terebra constricta* H. C. Lea, and *Cerithium terebralis* Adams (a living New England species) with *Cerithium trilineatum* Phil., of Great Britain, France, Belgium, Germany, etc., and living in the Mediterranean; *Pleurotoma cristata* Conr., *Cochlespira bella* Conr., *C. engonata* Conr. with *Pleurotoma Volgeri* Phil., of nearly the same wide range abroad; *Saxicava bilineata* Conr. with *Saxicava arctica* L., of wide distribution, and now living on both sides of the Atlantic; and confirms Heilprin's identification of *Pleurotoma*

Beaumonti Lea with *P. denticula* Bast., after comparison with German specimens of the latter. Mr. Meyer also describes the new Claiborne species *Tibiella Marshi*, *Bulla biumbilicata*, *Cadulus depressus*. Mr. Meyer states further that in his opinion, and also Professor Verrill's, *Cadulus Pandionis* of Verrill and Smith, from the western part of the Atlantic, is identical with *Cadulus thallus* named *Dentalium thallus* by Conrad, from the Miocene of the Southern States; and that if Jeffreys is right, this species is identical with *Cadulus Olivi* of Scacchi from the Pliocene of Sicily. It is to be hoped that Mr. Meyer may be able to continue his study of American Tertiary fossils.

3. *The Geological and Natural History Survey of Minnesota, 11th Annual Report*, N. H. Winchell, State Geologist. 220 pp. 8vo. Minneapolis, 1884.—This report is occupied chiefly with a report on the minerals of the State by Mr. Winchell, on the crystalline rocks by Messrs. A. Streng and J. H. Kloos, and on the glacial and related phenomena of the Winnipeg region ("Lake Agassiz") by Mr. Warren Upham. The first of the reports states that gold has been washed from the drift at Rochester, Oronoco, Spring Valley, Jordan, in Fillmore County, and at several points in Wabasha County, and has been announced as taken from the gravel at Willmar.

4. *B. Lotti, of the Italian Geological Survey, on the origin of Tuscan Granite* (R. Com. Geol. d' Italia).—Signor Lotti, of Pisa, reaches the conclusion that the Tuscan granite is largely of metamorphic origin; that the granite, for example, of Mt. Capanne, on Elba, was formed largely at the expense of a rock which is "gneissic schist" elsewhere, and that whilst the conversion of the rock into granite is general on the western side of Elba, it is only partial on the eastern. The reduction of the rock, as he observes, to a pasty state through the metamorphic process determined the formation of the granite, and also of veins of granite through its protrusion into fissures in the schistose rocks.

5. *Manual of the Mosses of North America;* by Leo Lesquereux and Thomas P. James. With six plates illustrating the Genera. Boston: S. E. Cassino & Co. 1884. pp. 447, post 8vo. —At length this much-needed and long-promised volume is in the hands of botanists and students, and the department of Bryology, so far as concerns the orders of the Peat-Mosses, Schizocarpous Mosses and True Mosses, is provided for. As long ago as the year 1848, and so far as relates to the Northern United States, some provision was made for their study, in the first edition of Gray's Manual, by a contribution from Mr. Sullivant, the founder of bryological study in this country. And when, in 1856, that work passed to a second edition, about 100 pages of this were devoted to a reëlaboration of the Mosses and the Liverworts by the same friendly and able hand. Mr. Sullivant also contributed eight admirable copper-plates, crowded with figures. This contribution, also separately issued in a small edition, did excellent service. It was thought best to drop these lower Cryptogamia

from later editions of the Manual, on the understanding that Mr. Sullivant, on the completion of his sumptuous *Icones Muscorum*, would prepare a synopsis of all the North American Mosses. But early in the year 1873, just as this accomplished bryologist was setting himself to the task, he was taken away by an attack of pneumonia. The authorship of this work was to be shared with his associate and near friend, Mr. Lesquereux. But Mr. Lesquereux was deeply engaged in paleo-botany, and could only from time to time snatch some moments for bryology. When the time arrived in which he could seriously give himself to this work, his eyesight was so impaired that he could seldom use the microscope. He now solicited the coöperation of the late Mr. James, an acute bryologist, who, being comparatively free from other engagements, could devote himself to the microscopical investigation and illustration of Mosses, in which he had long been an adept. With this important accession the preparation for this work went on successfully until, in February, 1882, Mr. James, who had reached his 79th year, suddenly died, and the work again devolved upon our aged and sole surviving bryologist. But at length, with the generous and needful editorial aid of Mr. Sereno Watson (which is gracefully acknowledged in the preface), the work is at length completed and published. It is handsomely printed, in a type which we should consider needlessly large. Mr. Sullivant's five copper-plates of the Mosses are well reproduced by transfer from the coppers, and a sixth is added for the Hypnoid genera or subgenera, taken from Schimper. An acknowledgment was due to the Sullivant family for the use of these plates, the omission of which was evidently a pure oversight. As to the genera, Schimper is closely followed. This was natural; but if the authors could have followed their own convictions the genera would probably have been fewer, more easily recognizable, and more accordant with the idea of genera in phænogamous botany. We may hope that this loss of a sense of proportion—a malady incident to specialists—will some day be remedied, and that genera in Mosses will again be characterized upon the organs of fructification rather than upon the shape of the cells of a leaf. It would have been well to have marked the principal accent of the generic and specific names. But we will not find fault with a work for which we cannot be too thankful. Let us rather felicitate the venerable and sole survivor of our four bryologists, Sullivant, Lesquereux, James and Austin, upon this worthy conclusion of his labors; and let us hope that, under the stimulus of their example and by the aid offered in their works, and which is brought within the reach of all in this manual, a new generation of bryologists may spring up. This is still a matter of hope, not at all of sight. A. G.

6. *Synopsis of the Genera of Vascular Plants in the vicinity of San Francisco, with an attempt to arrange them according to Evolutionary Principles;* by H. H. Behr, M.D. San Francisco: Payot, Upham & Co. 1884. pp. 165, 18mo.—The genera of a

limited district offer a small base for the development of "the idea of a classification founded on the phases of vegetable evolution;" still it may serve the author's purpose as well as a broader one would have done. The genera are said to be taken chiefly from "Dr. Asa Gray's Flora Californiensis." The title of the work thus referred to is the Botany of California, and the botanist mentioned as the author was only a contributor. A. G.

7. Boissier's *Flora Orientalis.*—The second part of the fifth volume was issued in April, 1884. It contains the *Gramineæ*, the *Gymnospermæ*, and the Vascular *Cryptogamia*, and so brings this great undertaking to completion, except for a supplement to the earlier volumes, upon which the indefatigable author is now engaged. The first volume was published in the year 1867. We need not wait for the soon-expected supplement before we offer our congratulations to the author for this happy completion of this task of twenty years, the more remarkable because accomplished single-handed. A. G.

8. *Contributions to the Flora of North Patagonia;* by John Ball, F.R.S., etc.—An article in the Journal of the Linnean Society, vol. xxi (1884), founded on a collection made by an amateur, M. Claraz, a Swiss gentleman; to which is prefixed some interesting remarks on the climate and indigenous botany of the region.

"The most remarkable feature in the flora of this region is its extreme poverty. . . . Putting together all that has been collected and published in Europe, I doubt whether more than 300 indigenous species can be said to be certainly known to grow south of the Rio Colorado. . . . It is certain that the extreme poverty of the flora of such an extensive continental area is a fact quite exceptional. . . . The causes of this poverty do not seem to me to have been adequately explained. Professor Lorentz is disposed to attach most importance to the uniformity and sterility of the soil and the rudeness of the climate. The soil of the plateau is no doubt both very uniform and very sterile; but similar tracts in other parts of the world support a very varied vegetation, and Engler has assigned good reasons for believing that dry soils are in general favorable to the development of new vegetable forms. Further, it may be remarked that the soil of the valleys must exhibit a sufficient degree of moisture, of constituents, and of exposition to favor the development of many species not yet established there.

"Still less can I admit the severity of the climate as an explanation of the poverty of the flora." And the author proceeds to demonstrate that the rainfall is not very scanty and is spread pretty uniformly over the seven warmer months of the year; and that neither the summer's heat nor the winter's cold are excessive.

"The true explanation, in my opinion, of the exceptional poverty of the Patagonian flora is to be sought in the direction long ago indicated by Charles Darwin, when, in discussing the absence of tree-vegetation from the pampas, he remarks that in that region, recently raised from the sea, they are absent, not because they

cannot grow and thrive, but because the only country from which they could have been derived—tropical and sub-tropical South America—could not supply species to suit the soil and climate. So it happened in Patagonia—raised from the sea during the latest geological period, and bounded on the west by a great mountain range mainly clothed with an alpine flora requiring the protection of snow in winter, and the north by a warm temperate region whose flora is mainly of modified sub-tropical origin—the only plants that could occupy the newly-formed region were the comparatively few which, though developed under very different conditions, were sufficiently tolerant of change to adapt themselves to the new environment. The flora is poor, not because the land cannot support a richer one, but because the only regions from which a large population could be derived are inhabited by races unfit for emigration. The rapidity with which many introduced species have spread in this part of South America is perhaps to be accounted for, less by any special fitness of the immigrant species, than by the fact that the ground is to a great extent unoccupied."

The published list adds two or three to the considerable number of species in temperate South America—especially on the eastern side—which are identical with temperate North American species.

A. G.

9. *Change of the generic name Solenotus;* by ALFRED C. STOKES, M.D. (Communicated.)—In the July number of this Journal, on page 38, the writer describes a new genus of Infusoria under the name *Solenotus*, not being aware at the time that it was preoccupied. As a change is necessary I substitute the word *Notosolenus* (νῶτος, back; σωλήν, groove), the species then standing *Notosolenus apocamptus* and *N. orbicularis.*

Trenton, N. J.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Prehistoric man in Egypt and Syria;* by DR. DAWSON. (Proceedings of the Victoria Philosophical Institute of London, May, 1884.)—In dealing with his subject, Dr. Dawson remarked that, great interest attaches to any remains which, in countries historically so old, may indicate the residence of man before the dawn of history. In Egypt, nodules of flint are very abundant in the Eocene limestones, and, where these have been wasted away, remain on the surface. In many places there is good evidence that the flint thus to be found everywhere has been, and still is, used for the manufacture of flakes, knives and other implements. These, as is well known, were used for many purposes by the ancient Egyptians, and in modern times gunflints and strike-lights still continue to be made. The débris of worked flints found on the surface is thus of little value as an indication of any flint-folk preceding the old Egyptians. It would be otherwise if flint implements could be found in the older gravels of the country. Some

of these are of Pleistocene age, and belong to a period of partial submergence of the Nile Valley. Flint implements had been alleged to be found in these gravels, but there seemed to be no good evidence to prove that they are other than the chips broken by mechanical violence in the removal of the gravel by torrential action. In the Lebanon, numerous caverns exist. These were divided into two classes, with reference to their origin; some being water-caves or tunnels of subterranean rivers, others sea-caves, excavated by the waves when the country was at a lower level than at present. Both kinds have been occupied by man, and some of them undoubtedly at a time anterior to the Phœnician occupation of the country, and even at a time when the animal inhabitants and geographical features of the region were different from those of the present day. They were thus of various ages, ranging from the post-Glacial or Antediluvian period to the time of the Phœnician occupation. Speaking as a geologist, from a purely geological point of view, and from a thorough examination of the country around, there was no doubt but what there was conclusive evidence that between the time of the first occupation of these caves by men—and they were men of a splendid physique—and the appearance of the early Phœnician inhabitants of the land, there had been a vast submergence of land, and a great catastrophe, aye a stupendous one, in which even the Mediterranean had been altered fron a small sea to its present size. In illustration of this, the caverns at the Pass of Nahr-el-Kelb and at Ant Elias were described in some detail, and also, in connection with these, the occurrence of flint implements on the surface of modern sandstones at the Cape or Ras near Beyrout; these last were probably of much less antiquity than those of the more ancient caverns. Dr. Dawson's address was illustrated by flint implements and bones collected by him during his recent tour in the East.

2. *New England Meteorological Society.*—This society has recently been organized in Boston with the aim of advancing the science of meteorology and bringing into coöperation the many observers and students of the weather in New England. At the outset, it is proposed to institute a relatively limited system of observations at as many stations as possible, probably not going beyond rainfall and temperature range; but with the successful growth of the society, the plan of work will be enlarged. Mr. Winslow Upton, lately of the U. S. Signal Service, now Professor of Astronomy at Brown University, will act as director of observations; and early in the autumn, the council of the society hopes to begin the issue of a monthly bulletin summarizing the results obtained. All persons interested in the aim of the society, whether they can take part in the work of observation or otherwise give support to its objects, are invited to send their names to W. M. Davis, Secretary, Cambridge, Mass.

Transactions. Vol. 1.—The Royal Society of Canada consists of

3. *Royal Society of Canada*, 1882 *and* 1883. Proceedings and

four sections. I, French Literature, History and allied subjects; II, English Literature, History and allied subjects; III, Mathematical, Physical and Chemical sciences; IV, Geological and Biological sciences. This first volume contains 16 papers in section I, 9 in section II, 24 in section III and 24 in section IV, showing great scientific activity in the academy during its first two years. Some of the papers have already been noticed in this Journal.

4. *Royal Society of New South Wales*, vol. xvi, 1882.—Mr. A. Liversidge describes in this volume the Deniliquin or Baratta meteorite. H. Tenison-Woods is disposed to refer the extensive sandstone formation of eastern Australia, named the Hawkesbury Sandstone, chiefly to wind transportation, an opinion the writer's observations (Wilkes Expl. Exped. Geol., 1849) do not appear to him to sustain. The same author describes Mesozoic fossils from Palmer River, Queensland. Mr. H. C. Russell has a paper on Tropical rains illustrated by maps.

Census Reports on Cotton, E. W. Hilgard, Special Agent in charge:

(1) General Discussion of the Cotton Production in the United States, by E. W. Hilgard.

(2) On the Cotton Production and Agricultural features of Mississippi and Louisiana, by E. W. Hilgard.

(3) Physical and Agricultural features of California, with a discussion of the present and future of Cotton production in the State; also Remarks on Cotton Culture in New Mexico, Utah, Arizona and Mexico, by Dr. E. W. Hilgard.

(4) On the Cotton Production and Agricultural features of Georgia, Texas, Arkansas and the Indian Territory, by Dr. R. H. Loughridge, Special Census Agent.

(5) On the Cotton Production and Agricultural features of Alabama and Florida, by Dr. Eugene A. Smith, Special Census Agent.

Geological and Mineral Studies in Nuevo Leon and Coahuila; by Dr. Persifor Frazer. 36 pp. 8vo, with maps. Philadelphia, 1884.

Types of Animal Life selected for Laboratory use in inland districts; by C. L. Herrick. Part I, Arthopoda. 34 pp. 8vo, Minneapolis, 1883.

German Upper Devonian Phyllopod Crustaceans. Professor J. M. Clarke (of Northampton, but for the year past in Germany) has described and figured, in the Jahrb. f. Min., i, 1884, three species of *Spathiocaris* and one of *Entomis*, from Bicken, and one of *Dithyrocaris* from Wildungen.

Der Tarsus der Vögel und Dinosaurier, eine morphologische Studie; von Dr. Georg Baur, aus München. 44 pp. 8vo, with two plates. An important paper.

Niagara fossils; by J. W. Spencer. 62 pp. 8vo, with several plates; including Graptolitidae and Stromatoporidæ of Upper Silurian, and fifteen new species of Niagara fossils. May, 1884. Printed for the Museum; also Proc. St. Louis Acad. Sci., vol. iv, no. 4. St. Louis, 1884.

The succession in the Archæan rocks of America compared with that in the Pre-Cambrian rocks of Europe, by Henry Hicks, F.G.S. Proc. Geologists' Assoc., vol. viii, no. 5.

Geology and Mineral Resources of the James River Valley, Va.; by J. L. Campbell, Professor Geol. and Min., Lexington, Va.; 120 pp. 8vo, with a map and Geological Sections. The work is a contribution to general as well as economic geology.

OBITUARY.

Ferdinand von Hochstetter, the able geologist of Vienna, who was connected with the Austrian expedition around the world of the Novara, from 1857 to 1860, died on the 18th of July, in his fifty-sixth year.

APPENDIX.

Art. XXI.—*On the United Metatarsal Bones of Ceratosaurus;* by Professor O. C. Marsh.

In the April number of this Journal (vol. xxvii, p. 331), the writer described a remarkable new Dinosaur, the type of the genus *Ceratosaurus*, and of the family *Ceratosauridæ*. The skull, vertebræ, and pelvis were described and figured, but at that time little was known about the feet. More recently portions of these have been recovered from the same individual, and they prove to be as remarkable as the other parts of the skeleton already made known.

The most interesting feature in the extremities of this Dinosaur is seen in the metatarsal bones, which are completely ankylosed, as were the bones of the pelvis. There are only three metatarsal elements in each foot, the first and fifth having apparently disappeared entirely. The three metatarsals remaining, which are the second, third, and fourth, are proportionally shorter and more robust than in the other known members of the order *Theropoda*, and, being firmly united to each other, they furnish the basis for a very strong hind foot.

In figure 1, these coössified metatarsals of *Ceratosaurus* are represented, and for comparison the corresponding bone of a penguin is given in figure 2.

In comparing these two figures, it will be seen that the three metatarsal elements of the Dinosaur are quite as closely united as those of the bird. To the anatomist familiar with the tarso-metatarsal bones of existing birds, the specimen represented in figure 1 will appear even more like this part in the typical birds than the one shown in figure 2.

The position of the foramen, as seen in figure 1, *f*, is especially characteristic of recent birds, and, as a whole, the hind foot of this Jurassic Dinosaur was evidently similar to that of a typical bird.

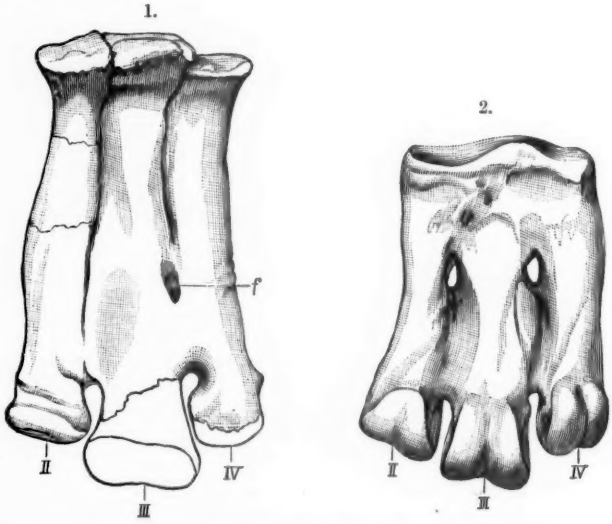

Figure 1.—United metatarsal bones of *Ceratosaurus nasicornis*, Marsh; left foot, front view. One-fourth natural size.
Figure 2.—United metatarsal bones of great Penguin (*Aptenodytes Pennantii*, G. R. Gr.); left foot, front view. Natural size.

All known adult birds, living and extinct, with possibly the single exception of *Archæopteryx*, have the tarsal bones firmly united, while all the *Dinosauria*, except *Ceratosaurus*, have these bones separate. The exception in each case brings the two classes near together at this point, and their close affinity has now been clearly demonstrated.

Yale College, New Haven, July 23d, 1884.